Jamie Carter

ASTRONOMER'S POCKET FIELD GUIDE

A Stargazing Program for Beginners

A Pocket Field Guide

Astronomer's Pocket Field Guide

More information about this series at http://www.springer.com/series/7814

Jamie Carter

A Stargazing Program for Beginners

A Pocket Field Guide

Springer

Jamie Carter
Cardiff, UK

ISSN 2198-0756 ISSN 2198-0764 (electronic)
Astronomer's Pocket Field Guide
ISBN 978-3-319-22071-0 ISBN 978-3-319-22072-7 (eBook)
DOI 10.1007/978-3-319-22072-7

Library of Congress Control Number: 2015950843

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

This book is for Gill, my binary star,
who loves the Pleiades
(but can’t pronounce it),
and for my parents, who taught me to
ask questions and read maps.

Preface

Every night, the Universe is talking to you. It's time to listen.

Most people have, at some point, gazed up at the night sky from a remote place and felt overwhelmed by a "blanket of stars." But there is no blanket. The night sky has depth, and it can be navigated. It can be known. Everything you've ever heard about space, planets, comets, NASA missions, and distant galaxies drifts above your head each night. With nothing more than patience, a few hours to spare each month, and clear skies, the Universe is yours to explore.

Stargazing is easy; you don't need an advanced education in astrophysics to understand the rhythms and celestial geography of the night sky. You just need to take the time to watch it all happen.

Unlike most stargazing guides, this book is not merely a list of seasonal sights in the order you should view them. Instead, it's an attempt to gradually build up your observing skills and visual knowledge of the night sky. This 12-month journey will allow the night sky to slowly expose its secrets as you witness one full orbit of the Sun. It's a journey that will repeat every year for the rest of your life and far beyond it, as those same stars will be rising and setting. The night sky is nothing if not predictable, but only for those who know the rules.

There is no big reveal. The map is always moving. Stargazing is about gathering new pieces of the jigsaw each month. By learning a few basics about the distances to some of the major stars and objects in the night sky, it's possible to begin to see shape and scale.

Seeing depth is the hard part; seeing back in time is shockingly simple. The last sunset you watched happened eight minutes before you saw it; that's how long it takes light—which boasts the fastest speed of all—to travel the 93 million miles from the Sun to the Earth. The next nearest star's light takes almost five years to reach us. From the next galaxy it takes 2.5 million years. Are we looking back in time? You could say that, or you could say that time is chasing us. Either way, after spending a year stargazing you'll live in a far bigger place than you do today.

Navigating the vast cosmos is easier than you think. You probably don't need to know how to cross oceans using only the stars as your guide, but it's nevertheless an easy skill to master. It takes just five minutes to learn how to find north from anywhere above the equator. After just a few short stargazing sessions you'll be able to point out several constellations and major stars, and know their incredible stories. After only a few months of observing, you'll instinctively know where the planets are and where the Moon is, even when you can't see any of them. Once a year has gone by and the stars you first saw in January have returned to the night sky, you will have observed one complete

orbit and seen the Universe in its entirety for the first time. In doing so you will have learned how to visualize Earth's astonishing journey around the Sun, and you will have witnessed a tiny part of the Sun's gradual journey through the Milky Way.

If that all sounds like philosophy and geography more than hard science, it should. Stargazing is too often associated with telescopes and astrophysics. So critical is math in the modern approach to astronomy that the number of humans who appreciate the night sky and its rhythms is dwindling. It's an oxymoron: as public interest in the discoveries continues to increase, fewer and fewer of us appreciate the night sky. We've gained a lot of astronomical knowledge, but we've lost the context.

This is not an astronomy book. Although it could act as a good grounding in amateur astronomy, I've tried to focus on gaining some cosmic perspective, through stargazing, on the distances and scale of the night sky. To keep things simple I have rounded up to the nearest light year and included only stars that can be seen by the naked eye or when using only basic equipment. There's plenty of information included about forces at work in the night sky that you can't see, but the focus is on visible stars, constellations, star clusters, galaxies, and planets. I've also used star names in place of astronomical designations, which has often meant using Arabic names that have various phonetic spellings. The specific demarcations of the various constellations do change depending on the books, apps, or star charts you use; I've stuck with those most familiar to me, and I make no apology either for taking the odd shortcut or for including two asterisms of my own, Felis Major (Chap. 3) and the Baby Giraffe (Chap. 6). Once you're familiar with the night sky you'll begin to find your own constellations, too. That's what stargazers do.

As well as the vital constellations and clusters, and the weird and wonderful nebulas, we'll also discover some dark sky destinations across the globe that help increase knowledge and give a new perspective on familiar night sky sights. Travel broadens the mind, and stargazing can be a journey in more ways than one. By year's end the reader will be able to glance at the night sky from anywhere on the planet and tell in what direction they're facing, where all the planets are, and even where Galactic Center Point is. Now how's that for celestial geography?

While I've included a mix of what I call flat and deep knowledge, there's an emphasis on the latter. Star names, constellations, and the myths associated with them all come from humans, and while they're certainly interesting, they tell us more about the human story than they do about what's really going on up there. It's the science in the stars, not their fictional stories, that most astounds. Deep truths about the distances of stars, their relation to one another, and the rhythms of the cosmos will all be explored. You really can have it all just while standing in your backyard.

The naked eye can go a long way in stargazing, but only so far. In this book, we will use binoculars (from April) and telescopes (from September) because they're so useful for studying the sky and getting a deeper understanding. They're optional, but for many stargazers, they prove irresistible. We're some of the first people in existence to have both access to inexpensive binoculars and

telescopes, and a real scientific understanding of what's actually going on in deep space. Many astronomy guides make the point of saying that stargazing has little to do with equipment and then proceed to offer pages of detailed advice on which telescope to buy. Since that advice is already out there and constantly being updated, I see no need to repeat it. The basics are covered, but those who require exhaustive advice on equipment should look elsewhere; this book is about the stars. Naked eye targets are therefore included all the way through this book; we will learn just as many new constellations in December as in January.

This book presumes you live in mid-northern latitudes, in the northern hemisphere. That includes continental USA and Europe. All times, celestial signposts and navigation tips are given for 10:00 p.m. on the first day of the month; this translates to around 8:00 p.m. toward the end of the month. You will soon understand why.

Some may wonder why I've included *mind's eye* targets—such as galactic features and the location of possible alien worlds—alongside easy-to-see constellations and stars. The night sky is not what it seems. It takes various levels of equipment to see into its different layers. If you want to know the night sky and its greatest sights, you need to know its ways and its geography, and that means learning about things that perhaps you can't see with your own eyes. These mind's eye targets are designed to bring valuable context.

I've also included a few human interest targets, from the International Space Station and the exact positions of the Apollo landing sites on the Moon, to space probes now on the outer reaches of the solar system. In this book, you'll learn in which constellations the Voyager probes are, and even where Halley's Comet resides in the night sky, waiting patiently for its return trip around the Sun. I make no apologies for including objects like these; they're simply objects I wanted to know the location of as I began to stargaze.

Stargazing and astronomy are not subjects for one book. Inside you'll find recommendations for websites, apps, podcasts, and other books; the best way to learn isn't by sticking to one source, but many. This book is therefore intended only to offer an active introduction to a lifetime of stargazing.

After the year is up, the stars and constellations you first saw many months ago will return like old friends, and the Universe will feel like what it really is: your home.

Cardiff, Wales Jamie Carter
June 2015

Acknowledgments

Thanks in writing this book primarily go to my wife Gill for her total support. Spending hours standing in the dark, sometimes on freezing mountainsides at 13,000 feet, while I was looking for constellations and clusters is the definition of "going above and beyond." In addition to her photography and assistance in the production of this manuscript, Gill also helped develop many of the star charts and figures. The *Felis Major* asterism (Chap. 3) I found in the stars is for her.

The figures were created using the excellent *Cartes du Ciel/Skychart* (www.ap-i.net/skychart/en/start) planetarium software, beloved by so many amateur astronomers. The plush *SkySafari* (www.southernstars.com) planetarium software also proved invaluable for stargazing during the day and for fact checking. Since *SkySafari* draws on the awesome **Stars** book and website (stars.astro.illinois.edu/sow/sowlist.html) for its information, thanks also go to its creator, Jim Kaler, Professor Emeritus of Astronomy, University of Illinois.

Thanks also go to Chris Bramley, Editor at the BBC *Sky At Night* magazine (www.skyatnightmagazine.com), for giving me a reason to go in search of dark skies, and to Stephen Tonkin, whose brilliant monthly "Binocular Tour" in the same magazine first got me outside with a star chart.

There are those who have inspired and fueled my interest in the night sky, not least those who have hosted me in the various dark sky destinations across the globe that I've been lucky enough to visit. Generosity, enthusiasm, and valuable telescope time came from Jane Morgan at the Cosmos Centre and Observatory (www.cosmoscentre.com) in Charleville, Queensland; Richard Cooke at Stargazers Retreat (www.breconcottages.com/cottages/brecon/stargazers-retreat) in the Brecon Beacons, Wales; everyone at Lowell Observatory (www.lowell.edu) in Flagstaff, Arizona; and the staff at Planetarium Cusco (www.planetariumcusco.com) in Peru. I enjoyed stargazing with you all. Thanks to Jérome Brun for driving me up the unfathomable road through the clouds to Pic du Midi Observatory (www.picdumidi.com) and to Hautes-Pyrénées (www.tourisme-hautes-pyrenees.com), Argelès-gazost (argeles-gazost.com), and Villa du Parc (www.lavilladuparc.fr) for their hospitality.

To the inspirational Christian Luginbuhl and Lance Diskan at Flagstaff Dark Skies Coalition (www.flagstaffdarkskies.org): it was great talking to you both. May the darkness you've worked so hard for always prevail in your precious town.

Chasing eclipses is an expensive hobby, so I'm indebted to both Explorers Astronomy Tours (astronomytours.co.uk) and Visit Faroes (www.visitfaroeislands.com) for their incredible generosity in allowing me to stand dumbfounded under the path of total solar eclipses in Queensland and the Faroe Islands in November 2012 and March 2015, respectively. Invaluable help hunting the

Northern Lights came from The Aurora Zone (www.theaurorazone.com) and from ace aurora photographer Gareth Hutton (adventurebydesign.fi), who will recognize many of the photos in Chap. 14 and mourn the lack of “aurora selfies.” Thanks also go to eclipse photographer *par excellence* Nick Glover, Tyler Nordgren (www.tylernordgren.com), the European Southern Observatory (ESO), the European Space Agency (ESA), and NASA for permission to use their superb photography and artwork.

Lastly, I apologize to anyone at an observatory, planetarium, or stargazing event who promised to explain the night sky before wading through the mythology of ancient Greece. As my glazed expression may have indicated, I was waiting for the real story.

About the Author

Jamie Carter is a journalist based in the United Kingdom with 17 years experience of communicating science and technology via articles in magazines, newspapers, and online. In his work as a travel journalist, he has written several eyewitness articles and has reported on everything from the aurora borealis, total solar eclipses, and stargazing to dark sky destinations, astro-tourism, and astro-photography. His work has been published by the BBC *Sky At Night* magazine and website, Mashable, MSN, LifeHacker, The Guardian, Real Travel, Travelsupermarket and Hong Kong's *South China Morning Post* newspaper, for which Jamie is a regular columnist. Jamie also owns and edits the TravGear.com website.

While reporting from under some of the darkest skies the world has to offer, Jamie became convinced that stargazing should be an essential part of any trip or outdoor vacation. His efforts to learn as much as possible about the night sky in one calendar year led to some intensive research, incessant stargazing, and an unexpected obsession with the lunar calendar. It also led to a series of articles for the BBC *Sky At Night* magazine, which inspired this book.

Jamie lives in Cardiff, Wales, swapping its light-polluted skies for those of the nearby Brecon Beacons International Dark Sky Reserve whenever he gets the chance.

Contents

Appendix

PART I

THE WIDE-EYED VIEW

CHAPTER 1

JANUARY: WHERE AM I?

The Stars of January

January's skies are the darkest, clearest and longest of the entire year, and contain some of the most prominent, beautiful and memorable stars and patterns, so it's the ideal time to begin. From finding your first constellations—including the Big Dipper (also known as the Plough) and Orion—to star-hopping through the night sky, by month's end you will have memorized some important anchors, and have begun to watch the hypnotic rhythms of the stars' apparent movements. However, for northern hemisphere stargazers, it's cold outside, so some bite-size stargazing is the way to go in January (Fig. 1.1).

How to Stargaze

Let the night sky slowly sink in and it will always stay with you, wherever you go, and whatever you do. Think about what it is you're about to do. Going outside and getting confused won't get us anywhere, and with temperatures hovering around freezing at this time of year in much of the northern hemisphere, it's important to know what you want to achieve—and to do it as quickly as possible. January is a time for speed-stargazing.

The night sky takes an entire year to get to know; the stars you see tonight will be in the same positions again exactly a year from now. It's huge, it's always moving, and it can seem complicated at first. All you can expect to do in one stargazing session—particularly your first-ever attempt—is to see a single snapshot. Over the coming weeks and months these snapshots, sights, constellations and stars will become woven together in your mind. They'll get context, and their movements will begin to make sense.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_1

Fig. 1.1 The Big Dipper, also known as the Plough, one of the most recognized group of stars in the night sky. Credit: NASA

The stars aren't going anywhere, so there's no rush; choose your battles, keep warm, learn slowly, and repeat the stargazing activities in this book again and again until they become second nature.

Where to Stargaze

There's no need to jump in the car and drive into the middle of the desert (at least, not yet!). Find somewhere convenient, such as your own backyard, the sidewalk out front, a local public park, a field or a beach. Try to choose somewhere that doesn't have any lights in your field of view (street lights and motion-sensing security lights are a stargazer's biggest enemy). There's not much you can do about public lighting, but if a neighbor has a bright, white security light, ask them nicely to turn it off. It's imperative that you get away from direct lights that dazzle you. However, just as important is that you have a clear view of as much of the sky as possible.

When to Stargaze

Like all learning, stargazing is best done little and often. That way, the things you learn will slowly sink in through repetition. In the beginning, aim to stargaze just once or twice a week, for about 30 minutes each.

It's technically possible to see a whole six months' worth of night sky patterns if you stay up all night. Few of us have the time or the addictive personality to completely switch our body clocks and stay up all night stargazing. It's not practical, which is why this book—and all stargazing books, for that matter—presume that stargazing is done for a relatively short time at about the same time each day.

Glimpsing at the night sky at 4:00 a.m. can be quite exciting; what you see is your stargazing sessions fast-forwarded, with constellations rising that you otherwise wouldn't see for many weeks or months during the early evening. However, for the sake of being practical, and for properly gaining an understanding of how the night sky changes gradually each night as Earth orbits the Sun, it's best to stargaze at around the same time each night; this book presumes 10:00 p.m., which applies all year round, though stargaze a few hours earlier in winter if you would rather.

In reality, clear skies will determine exactly when you get to do any stargazing. Clouds don't stick to a timetable. An hour or so after sunset when darkness has descended, go outside and look up at the sky. If all you see is clouds, go back inside and watch TV, or read a book. Come back tomorrow.

That may seem like strange advice, but if you're going to be a stargazer, you're always going to need a Plan B. Even if you can see a few stars through gaps in the clouds, it's better to postpone your debut as a stargazer; at the start of your career you're after the big wide-eyed, wide-angle view of a clear sky.

Avoiding a Bright Moon

So you think moonlight is romantic? Most stargazers have a love-hate relationship with the Moon. It can easily ruin a (poorly) planned stargazing session, so much so that serious stargazers often cross-reference a lunar

Fig. 1.2 A bright Moon can make stargazing very difficult. © Jamie Carter

calendar with a diary and cross out an entire 10 days each month. If the Moon is big and bright, it acts like a giant light polluter and leaves even bright stars and constellations looking faint and washed-out (Fig. 1.2). It's far more light polluting than any streetlight, or even a big city center, billboard or filling station, but it is very predictable. See Chap. 3 for more on the Moon's phases, how and when to best see it, and when best to avoid it.

Where to Stand

A patch of grass or lawn is fine if it's going to be a brief stargazing session on a relatively warm night, but in January that's not likely. Stand on grass for too long and your feet will soon turn to ice.

Don't plan on staying outside for too long to begin with. There is only so much new knowledge one brain can take in, and after a while it resists. That goes double if you're learning how to find shapes and patterns in stars you don't recognize. Your neck will thank you for it!

What to Wear in Winter

If you're in the northern hemisphere then this is likely to be the coldest month of the year, so wrap up as warmly as you can; even 30 minutes in freezing conditions can be difficult. A stargazer's best friend usually isn't a book or an app, but a huge winter coat (and perhaps a hip flask, too). It's not just the cold you're battling, but the fact that you're not moving. If it's at or below freezing it's imperative that you take precautions and dress carefully. Waterproofing is important, too (though rarely for rain, since rain means clouds, which means no stargazing). However, dew can leave you soaked to the skin even on summer nights.

Feet

It's always the feet that go first; the biggest reason for cutting short a stargazing session is cold feet, but this is easily avoided. There are many kinds of socks that claim thermal properties, but one pair is never enough on a cold winter's night. Working on the principle that trapping warm air is the best way to retain heat in your feet, a pair of thin socks (preferably merino wool) worn under a pair of thick wool socks inside a pair of hiking boots works best.

Legs

For stargazing sessions, legs are perhaps less important than your extremities, but it's wise to wear a pair of thermal leggings under any pair of trousers, or double-layered thermal trousers. If later you decide to get a telescope or develop a taste for astro-photography and consequently spend more time outside (and more of it on your knees adjusting optics and tripods in dewy conditions), a pair of waterproof over-trousers is a must. If you can find some waterproof thermal trousers, even better (ski pants are perfect).

Core

Much more effective than one big jacket is using multiple layers for insulation, a tactic that is used by hill-walkers, hikers and survivalists. A wool or technical base-layer wicks away moisture to keep you dry, which is essential to stay warm (avoid cotton, which gets wet with sweat and can leave you freezing cold). Consider wearing a relatively thick long-sleeved base-layer, which hugely helps in preserving your core body temperature for longer. Next on should be a warm fleece or wool jumper to trap body heat—preferably with a hood—and then a down-jacket, which provides both warmth and a basic waterproof layer. Find a jacket with pockets, since you'll always have some kind of stargazing paraphernalia with you; having somewhere to easily stow a pen, notebook, flashlight, hat, gloves, lens caps (and not forgetting your hands) is very useful.

Hands

What you wear on your hands entirely depends on what you're going to be doing. When you're just starting out, you're likely to be consulting apps on a phone and books like this one on a tablet (remember to turn the brightness down), so a pair of either fingerless gloves or 'touchscreen' gloves—which let you swipe the screen of a smartphone or tablet—are ideal. In the depths of winter you'll almost certainly need a pair of thermal gloves, too; the warmest choice by far are a pair of mittens, which trap the warm air around your fingers. If you're just going to be stargazing without books or devices, either with the naked eye or with binoculars, then just a pair of mittens is the ultimate choice. If you later opt for a telescope, then you'll begin a (likely life-long) search for the ultimate fingerless gloves.

Head

If your fleece layer has a hood, that might suffice. Better is a hat designed for hikers that has flaps that cover the ears, especially if it's windy. In the depths of January, wearing a thermal hat with a double layering of fleece is a good idea, though any kind of inexpensive woolly hat will do.

Neck

Forget binoculars or star charts; a tubular neck-scarf is the ultimate stargazing accessory for any season. Positioned between fleece and hat, they cover the gap where a chill wind can easily get in and sap your heat, and ultimately your enthusiasm to stay outside. Balaclavas can be useful for the same reason—they often cover the neck—but if you've dressed well then you may find that it's just too much, and then overheating becomes a problem.

Don't Forget

A pair of headphones can be useful if you plan to listen to music or a podcast while you're stargazing. It's useful to thread the cables of your headphones under the fleece layer before you finish dressing. In-ear models are fine, but keep in mind that bulky over-ear models can double as earmuffs.

The 20 Minute Rule

Adapting your eyes to the dark will give you excellent night vision. It takes about 20 minutes for this phenomenon to occur, and if you get to that point and you haven't gotten bored and gone inside, congratulations! You're in the tiny fraction of humanity blessed with the most precious commodity of all—patience. It's every stargazer's biggest asset. Don't lose it.

You also don't want to lose the night, so make sure you've switched off all lights in the back of your house, such as those in the kitchen or bedroom. Even a flickering TV or lamp in a dark bedroom can prove hugely distracting.

As your pupils dilate, they produce a chemical called rhodopsin, which allows the cells in your eyes to become more sensitive to light. However, that doesn't mean you have to wait for 20 minutes before looking up. Step outside and almost immediately you'll perhaps see the Moon, a planet or two, and a few bright stars. After a few minutes constellations like the Big

Dipper will reveal themselves and soon become clearer. Faint stars will get brighter after 10 minutes, and after 20 minutes you'll see so much more starlight, possibly more than you've ever seen.

Three Ways to Go Star-Blind

White light is incredibly damaging to your night vision, and consequently your ability to pick out stars and constellations and sky. Night vision takes patience to build up, but only seconds to destroy. Avoiding these three common mistakes that most stargazers make will allow you to look at the night sky with dark adapted eyes and avoid accidentally resetting your night vision clock back to zero. Remember: every time your eyes see artificial light, you're another 20 minutes away from night vision.

DON'T:

1. Look at your smartphone.
   It's so tempting to put some music on, check something online, or even use a planetarium app, but looking at a phone's screen will destroy your night vision (Fig. 1.3). Even if you do those things carefully with the screen's brightness turned down low, or use a red-light mode within a specialist stargazing app (more on this in Chap. 2), there's a chance someone will send you a message or call you—and that bright call screen can undo all of your good work in a second. Put your phone away, or at the very least, stay in control of it by putting it in 'airplane' mode to prevent any calls.
2. Use your flashlight.
   If it's white, keep it out of sight! Reading anything—including a book, planisphere or a star chart—with a white flashlight is a bad idea. Flashlights need to be in red light mode, which is the only color of light that dark-adapted eyes can withstand. If your flashlight can't go red, consider buying a head-mounted flashlight that can (Fig. 1.4); that way you can read books, charts and maps with two hands. Though red light modes tend to be subdued, flashlights increasingly use ever more powerful and bright LEDs on normal white mode, so do be careful not to switch back while stargazing. That goes double if you're stargazing with someone else; a quick blast of 60 lumens in their eyes will make them star-blind for 20 minutes.

Fig. 1.3 Using a smartphone is the quickest way to lose your night vision. © Jamie Carter

3. Go back indoors.
   You've run out of coffee, you forgot to bring your stargazing manual, or you just need to check the score of a big game on the TV. It can be tempting, but resist all urges to go back indoors, where white lights and LED televisions will destroy your night vision.

The Truth About Light Pollution

The slow reveal of the stars isn't just down to the makeup of the human eye. Artificial light is everywhere and natural darkness is increasingly difficult to find. However, light pollution does the most damage when it's used as an excuse not to stargaze.

Light pollution is easiest to see when it's not clear; the clouds seem orange or yellow. If there's snow outside, as there may be in January where you are, the world can look luminous on cloudy nights. However, not only is there

Fig. 1.4 A flashlight with a red light mode will help preserve your night vision. © Jamie Carter

nothing you can do about light pollution, but the sky glow from towns and cities across the globe can actually work slightly in your favor. There are a lot of stars up there—over 4000 from a dark sky site—which is a few too many for the amateur stargazer to navigate. By blocking out faint stars and only allowing the bright stars to shine through, some light pollution will make your early forays into stargazing—and particularly spotting constellations—slightly easier. Being underneath a blanket of stars is a great experience, of course, but even experienced stargazers (most of whom live in cities) can get disorientated if you put them in a truly dark place. So relax about light pollution; later on this year you can learn to hate it.

The Sun

What's the Sun got to do with stargazing? While it's tempting to ask you to go into your backyard, lay on the ground and gaze up at the stars, in January that's not practical. Instead, here's an easy question: what's the

brightest star in the sky? It's the Sun, of course; stargazing isn't an exclusively nocturnal activity.

A Warning

Caution is needed here: never look directly at the Sun, and absolutely not with cameras, binoculars or unguarded telescopes, as they magnify the light and can cause injury and blindness. Partially blinded photographers and amateur astronomers will attest to that; I've even heard of one person that, while attempting to watch the most majestic of stargazing events, a total solar eclipse (Chap. 14), set fire to his shorts and his hair while using a telescope!

Naked Eye Target: The Sun

Here's your first stargazing target. Next time you're outside in the place you plan to stargaze from close to sunset, take note of the general position of the Sun (though take care to never look at it directly). To find out where it sets, visualize a line from the Sun to the nearest horizon; that's West.

Where the Sun sets and even rises might be something you know by intuition already, or you may never have noticed. If you already know where it sets, you can work out where it rises, too; face where the Sun sets, then turn 180°; you're looking in the direction of the next sunrise. Over the next few days note the apparent path of the Sun across the sky; you'll probably have noticed before that it's relatively low in the southern sky at this time of year.

The Sun and the Night Sky

At 'just' 149.6 million kilometers from Earth, the Sun is by far the closest star to us. However, it's sufficiently far away for its light to take 8 minutes to reach us. Therefore, we always see the Sun as it was 8 minutes ago. Now that we know where the Sun rises and sets, we also know where the stars will rise. Not only is the Sun a star in its own right, but the fact that Earth

orbits it, and rotates as it does so, is key to appreciating the constantly moving night sky. The stars appear to move precisely because Earth itself is moving around one of them, and spinning as it does.

Celestial Geography

It's a big Universe out there, but there's a fact about the stars that few know. All the stars you can see in the night sky with the naked eye are in our Milky Way—they are our immediate neighbors. There are fewer visible stars than you might think. On a clear night in a dark sky destination (at least 40 miles from a city), about 4000 can be seen, though if you are in the middle of a big city, it's going to be more like 15 or 20.

Finding Your Way Around

What is first needed is a map. Although stargazing apps can be useful when used sparingly (more on this in Chap. 2), a *star chart* (a simple black-on-white chart of the visible night sky for a specific month) is better. While lines on a page may seem far less impressive than the awesome graphics on a smartphone, they are also far less distracting. You will also have to carry a red lamp or torch to read one, but a star chart can help foster a deeper understanding of the night sky more quickly.

Download a Free Star Chart

Go online and download the latest monthly star chart[1] for either the northern hemisphere, the equatorial regions, or the southern hemisphere. It will contain not only a detailed all-sky map with the major constellations, stars, planets and Moon phases/dates (Chap. 3), but also a handy monthly sky calendar. The latter has information like: "February 13: Moon near Jupiter

[1] SkyMaps (www.skymaps.com) & Orion (www.telescope.com) both provide free PDFs to download and print.

in midnight sky, 6 hours Universal Time (another term for Greenwich Mean Time, which those in North America will be several hours behind)." Star charts also often have an index of major naked eye, binocular, and telescopic objects visible that month.

How to Use a Star Chart

Star charts are easy to use. They show the entire sky from horizon to horizon for a specific time, with the cardinal points indicated right around it. Though they show the stars' positions as fixed, a star chart can also account for the drift of the stars. If it's marked as being accurate for 10:00 p.m. on January 1, it will also be accurate for 9:00 p.m. on January 15 and 8:00 p.m. on January 31, to account for the changing position of stars (Fig. 1.5).

In the very center is the zenith, which is the point directly above you in the night sky. If it says 'south' on the section of the star chart at the bottom, face south. Bring the star chart up over your head and it should match what's above you. It's easy to check by identifying a bright and obvious constellation, such as Orion.

Because online star charts are updated and freely available to download and print, they tend to include the position of the planets. Star charts in books do not because while the movements of the stars are seasonal and identical each year, that's not true for the planets.

Using a Planisphere

While star charts tend to be produced only for a single month, a *planisphere* can be used at any time of year. Inside the planisphere is a map of every star and constellation viewable from the northern or southern hemisphere during an entire year, but a moveable window in the top disc only lets you see what's viewable on a specific date and at a specific time. Simply adjust the upper disc according to the date and time shown around the outside, and orient the entire planisphere so that the western

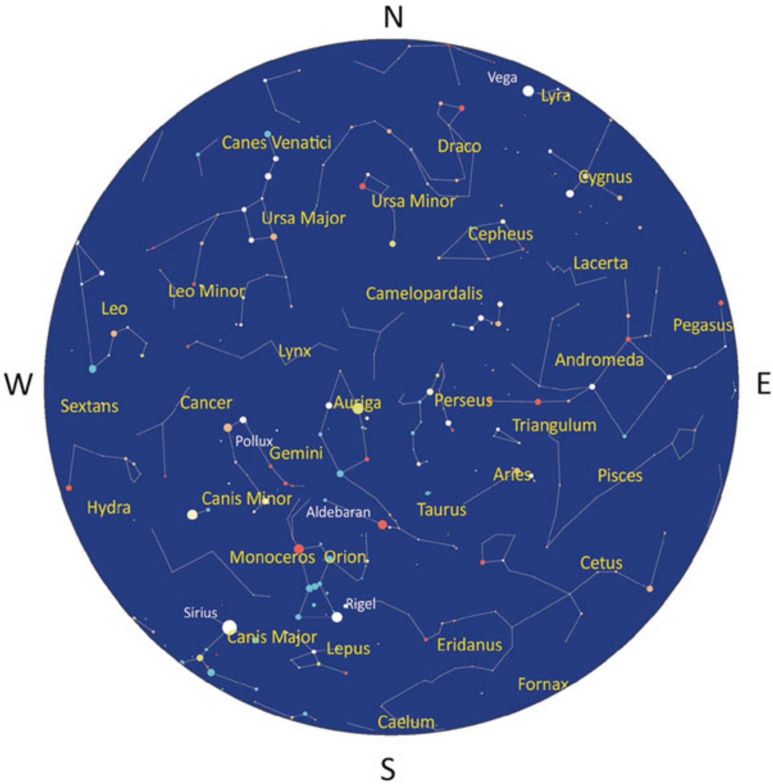

Fig. 1.5 A star-chart for January 1 at 10 p.m., which will be accurate for 9 p.m. mid-month and for 8 p.m. by month's end

and eastern horizons are in the correct place. You'll then have a map of the sky above you, which you can adjust slightly an hour later to account for the rotation of the Earth.

Although a planisphere is a great tool for understanding our seasonally changing view of the northern hemisphere stars—and I recommend you get hold of one—by their very nature they cannot show you the position of the planets. However, since they're of much higher quality construction than a paper star chart, the best planispheres often have a handy built-in advantage for stargazing: they also glow in the dark!

The Big Dipper

Here's your first constellation … or is it? Turn and face west—where the Sun went down a few hours ago—then turn to your right 90°. What can you see? The Big Dipper (Fig. 1.6) is familiar to most people: seven stars that make up a saucepan shape. In Britain it's known as the Plough.

If you're looking in the early evening, the Big Dipper will be almost flat and low in the sky, with the bowl shape on the right-hand side. Later in the evening during January, the Big Dipper will appear to be sideways, with the saucepan handle pointing down.

Pleased with your first constellation? Don't be; it's not even a constellation. Known to cultures both modern and ancient all over the world, the Big Dipper shape is actually called an *asterism*—a pattern—that's part of a much larger constellation called Ursa Major, the Great Bear (Chap. 3).

Naked Eye Target: The Big Dipper

The seven bright stars of the Big Dipper are instantly recognizable, and we're going to spend a few minutes with its constituent stars because they'll help us unlock two other great targets in the night sky. First let's look at the handle of the saucepan (Fig. 1.6); it's made up of five stars. Trace them with your eyes from the end of the handle, a star called Alkaid, to the second star, Mizar, then Alioth and, on the inside of the bowl, Megrez and Phad. On the outside of the bowl are Dubhe and Merak.

Our Nearest Star Cluster

The Big Dipper is the nearest star cluster to us. A *star cluster* is a group of stars that are gravitationally bound to each other. Unlike the stars of most constellations, five of the stars in the Big Dipper are relatively close to each other and are at about the same distance from us (about 80 light years, which as you'll soon discover, is pretty close), and were even born together (Couper and Henbest 2014). Called the Ursa Major cluster,

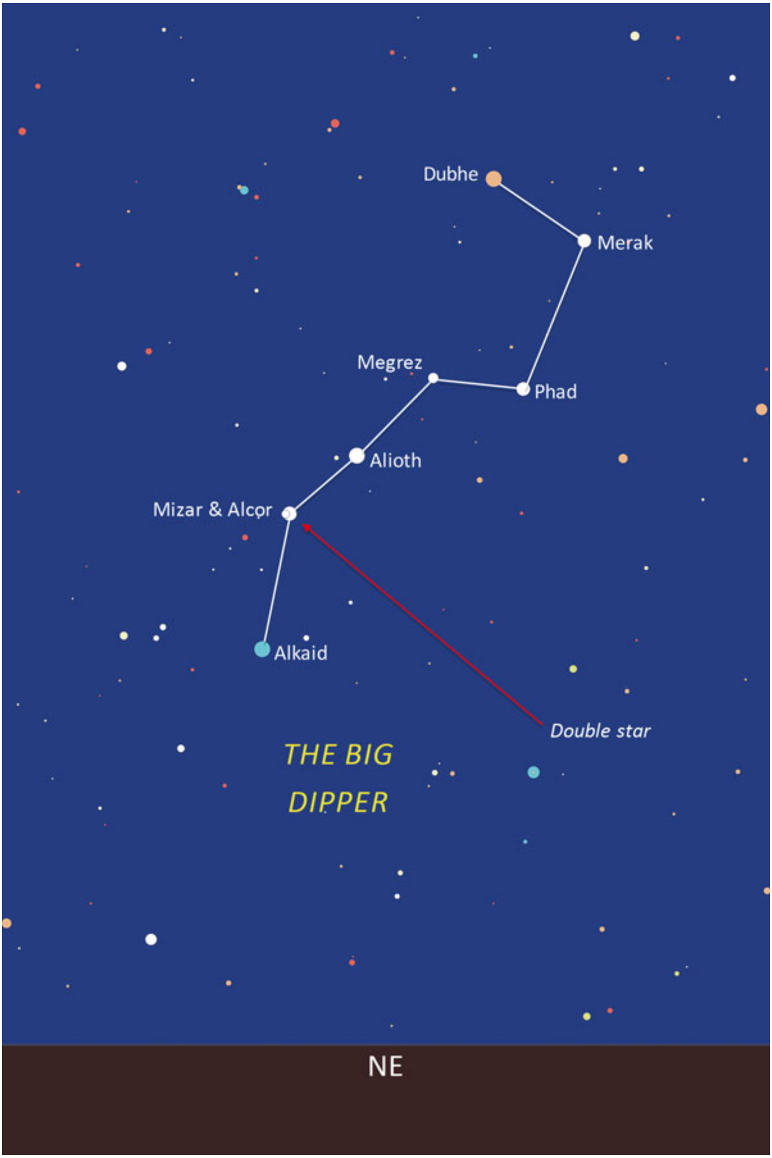

Fig. 1.6 The Big Dipper (also known as the Plough) is made-up of seven stars … or is that eight?

they're actually moving across the night sky in the direction of the constellation of Sagittarius (Chap. 7), which is seen above the southern horizon in summer.

However, two of the Big Dipper's stars—Alkaid at the tip of the tale, and Dubhe at the top of the bowl—are not related to the others. They're also both about 80 light years distant, but are moving away from the others. Come back in 100,000 years' time and Alkaid and Dubhe will have shifted to the right and the Big Dipper shape will be stretched and deformed. Enjoy it while you can!

Naked Eye Target: Mizar and Alcor

There's a reason it's called star 'gazing' and not star 'glimpsing.' Look carefully at Mizar. Now look at it again. Can you see a second, fainter star just beside it? If you can, your eyes are not deceiving you. Mizar has a friend called Alcor, a much smaller star, right next to it (Fig. 1.6). Nothing beats splitting two very close stars with your naked eye; it's a great lesson in the value of careful, persistent observing.

A Constant Constellation

But the best thing about the Big Dipper? If you're stargazing from the northern hemisphere, it's almost always present in the night sky, which is why almost everyone knows about it. It's part of one of the *circumpolar constellations*, which means that it moves around true north once every 24 hours. An easy way to remember where the Big Dipper will be during the year is the phrase 'spring up, fall down.' In spring, the Big Dipper will be above Polaris, and vice versa in fall.

The two most important stars in the Big Dipper for stargazing navigation are Dubhe and Merak, the outermost two stars that make up the bowl shape (Fig. 1.6).

How to Find the North Star

Everyone's heard of the north star, but can you find it? Easy—it's the brightest star in the night sky, right? Wrong. Actually, it's only the 48th brightest, which doesn't help much. Luckily, we can use Dubhe and Merak to point it out so precisely that you'll never lose it.

Naked Eye Target: Polaris, the North Star

Draw an imaginary line from Merak to Dubhe, and carry on for about five times the distance between those two stars (Fig. 1.7). The bright star nearest where you've got to is Polaris. While it may only be the 48th brightest in the sky, it is the brightest star in that region, and it's the one constant star. It never moves. Polaris is 430 light years from us, and it will appear higher in the sky the further north you travel. At the north pole, Polaris is always directly above, though technically speaking it's two-thirds of a degree off the exact north celestial pole around which the whole sky appears to rotate. If you stand at the north pole between October and March, not only will you see Polaris above you, but it will never stray from view; since the Earth's axis is pointing away from the Sun for six months, the Sun never appears over the horizon—and so the north pole is in constant darkness.

Why Doesn't Polaris Appear to Move?

At first glance, Polaris' seeming inactivity doesn't make any sense. The Earth is rotating at 1000 miles per hour, orbiting at 18 miles per second around a Sun that is itself orbiting the center of the Milky Way at 143 miles per second. How can it be that one star about 430 light years away appears to be fixed in the sky?

Well, despite the fact that stars are all orbiting the center of the Milky Way and moving through space at various speeds, for the purposes of stargazing, you can consider them fixed—you will not notice the position of any star shift during your lifetime. The one exception is Barnard's Star (Chap. 6).

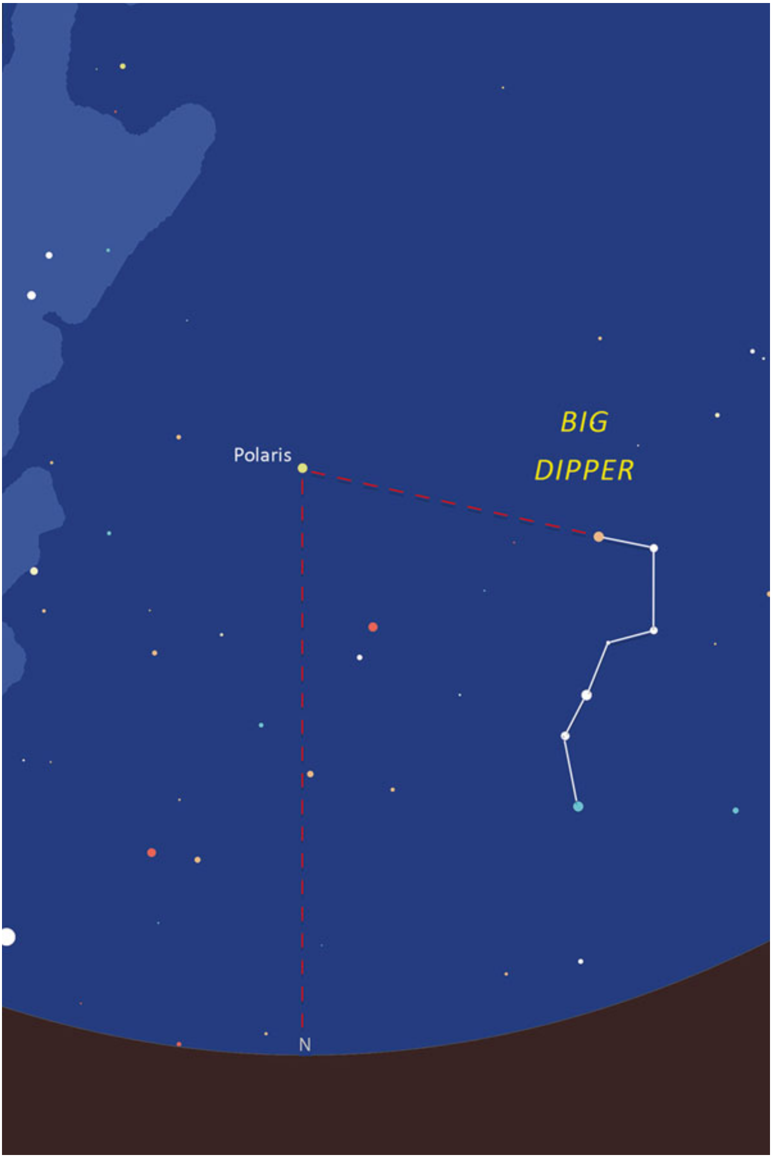

Fig. 1.7 How to find Polaris using the Pointers in the Big Dipper

Polaris is where the Earth's axis is pointed towards, so it lies directly above the north pole. Consequently, as the Earth rotates and the entire night sky appears to move, Polaris is the only star that appears to remain still.

The Truth About Polaris

In fact, Polaris does move slightly in our night sky; zoom in on a star-trail photograph centered on Polaris and you will see that it traces a circle—it's just a far smaller circle than produced by all the other stars. The cosmos is so vast that the actual movement of stars cannot be observed by the naked eye. Only specialist telescopes can measure the exact positions of stars and their movements.

The Moving Sky: How to See the Earth's Rotation

Look at the stars and they appear to be still. But stay outdoors long enough and you'll notice them shift. It's the Earth's rotation that makes the stars look like they're moving. Standing on the Earth's surface, we're all moving at 1000 miles per hour. You can't you feel it, but you can see it. Look at the sky at 5:00 p.m., and again at 10:00 p.m. before bed, and you'll notice that some stars that were close to the eastern horizon have risen much higher. The rising and setting of stars is caused by the rotation of Earth. This is one part of the rhythm of the night sky.

The Big Dipper Versus Cassiopeia

Having found both the Big Dipper and Polaris, the next target is our first real, whole constellation, Cassiopeia. Another of the night sky's anchors, it's a 'W' or 'M' shape in the same region of northern sky as the Big Dipper and Polaris. It should be easy to spot; it's always opposite the handle of the Big Dipper, with Polaris between them (Fig. 1.8). In January it's high in the sky, sinking later at night as the Big Dipper rises.

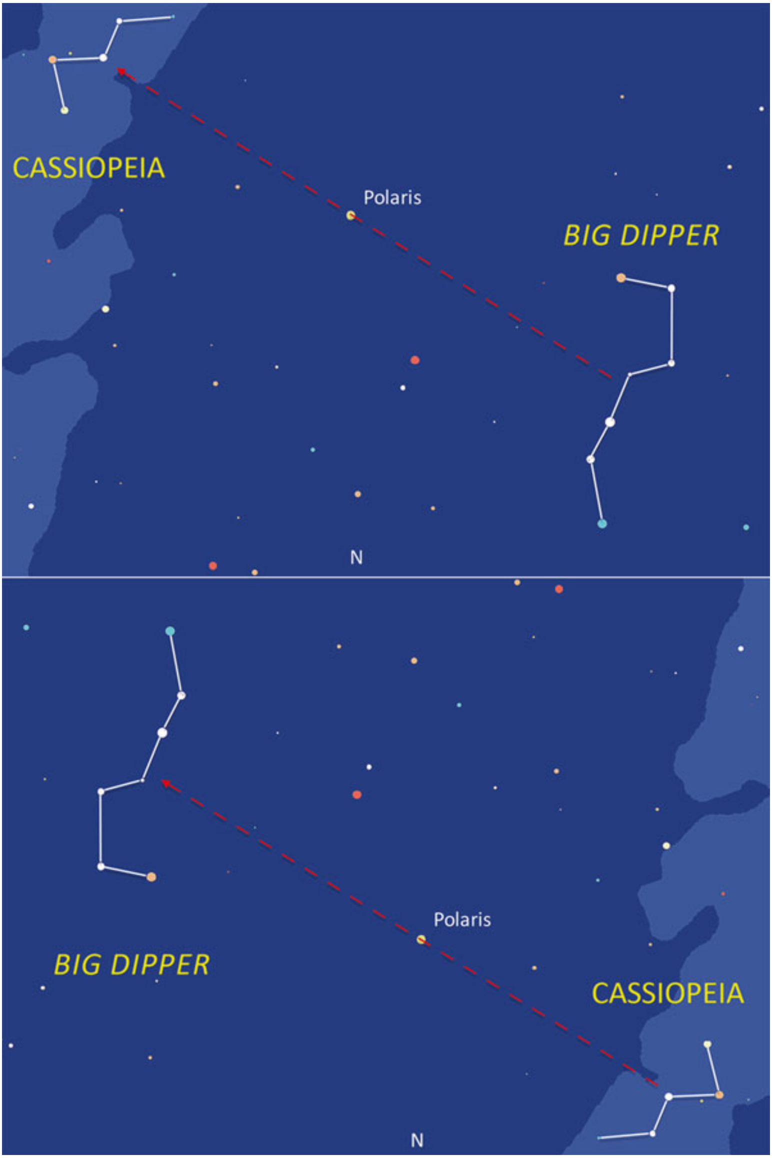

Fig. 1.8 The Big Dipper and Cassiopeia are always opposite each other in the northern sky

Naked Eye Constellation: Cassiopeia

Along with the Big Dipper, Cassiopeia is one of the sights that all stargazers instinctively look for. Not only is it easily visible and a cornerstone of the night sky in the northern hemisphere, but it also lies within the Milky Way. This constellation is made up from five stars; Caph, bright Shedar, Navi, Ruchbah and Segin (see Fig. 12.8 for a dedicated chart), none of which are particularly related to each other. If you're in a really dark location you'll notice a lot of stars around Cassiopeia. This is a region of the sky that is rich in star clusters.

Looking East

It's time to look away from the circumpolar sights and look to the east and south to some of the jewels of the January night sky. While everything we've looked at so far can be seen at any time of the year, what we're about to see is fleeting, and visible for a shorter time. On this side of the sky the stars appear to sweep from east to west if viewed constantly for a few hours, or at exactly the same time on consecutive nights, but for how long you'll see individual stars will depend on where you're stargazing from. The exact position of trees, your neighbor's house or a hill may mean that you can see specific stars and constellations for only a couple of months each year.

Sirius: The Brightest Star in the Sky

Sirius is actually the brightest star in the sky that we can see from the northern hemisphere. It's also known as Fool's Polaris since inexperienced stargazers often mistake it for the north star on account of its brightness. Sirius is the closest star to our solar system that we can view with the naked eye from the northern hemisphere.

Naked Eye Target: Sirius, the Brightest Star

Turn and face east. You should be able to see three bright stars in a row and, to their left and slightly below, another really bright star. You probably already know what those three stars are—Orion's Belt, which we'll come to

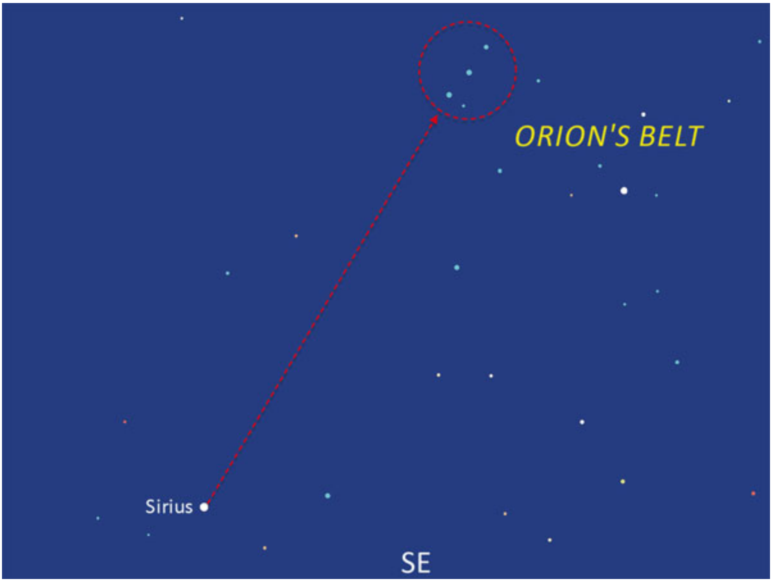

Fig. 1.9 How to locate Sirius, the brightest star in the sky

shortly. Place your outstretched fists, held together, on the left-hand side of the belt of stars and orientated in the same direction, and the edge of your left fist should just about reach a very bright star down towards the horizon (Fig. 1.9). This is Sirius, also known as the Dog Star because it's in the constellation of Canis Major, the Great Dog.

Almost twice as big as our Sun, Sirius in the winter months is due south by nightfall, though it never rises very high above the horizon. By summer, Sirius is rising in the east just before sunrise. The long, hot 'dog days' of summer were blamed by the ancient Greeks on the Sirius-rise, which was thought to give-off immense amounts of heat. In fact, Sirius has nothing to do with the hot months of summer, but it underlines how important the changing of the night sky has been in human history; the appearance of stars indicates the passing of the seasons.

The Sun Versus Sirius

Sirius is one of the Sun's closest neighbors, which is why it's so bright. It's actually the fifth-closest star (see Chap. 13 for the other closest stars), though the difference in distance from Earth compared to our Sun is staggering. While the Sun is 8 light minutes away, Sirius is 8.6 light years, so the light you see when you look at Sirius has taken 8.6 years to get here. That may seem like a lot, but on cosmic scale, it's very close. Such is the scale we have to get used to when stargazing into the void of space and time … and that's just our stellar neighborhood.

Star or Planet?

When looking at the very brightest stars in the night sky, it's very easy to get confused by an interloper or two—the planets. Of course, the planets can provide some of the greatest celestial sights any stargazer can see, but really only with binoculars or a telescope, which we'll come to later in the year. If you can see what you think is a bright star to the east, it's probably Jupiter. Since this giant planet orbits the Sun only every 12 years, it's a slow-moving presence in the same general area of sky for a year or so. However, that doesn't mean it's always visible; as Earth orbits the Sun, all planets will appear to be behind it at some point during the year, and therefore be impossible to see.

The Orion Illusion

You might think the three stars of Orion's Belt are so obvious and easy to see that you're more interested in learning about the rest of the sky. Think again. Not only will you spend the entire summer waiting for its return to the night skies, but Orion's Belt also contains one of the finest sights of all, the Orion Nebula (Chap. 2). Orion's presence to the south is a sure sign that you're in the period of the year when the very best stargazing is possible in the northern hemisphere.

Naked Eye Constellation: Orion

You've seen the brightest, now look at the best. Sirius appears to chase—or point to—Orion's Belt. However, it's not a constellation at all. Those three bright Belt stars are part of a much larger constellation—and one easily seen—simply called Orion (Figs. 1.10 and 1.11). The Belt is just an asterism. Throughout your first year of stargazing, we're going to see a lot of asterisms with descriptive and, usually, fairly modern objects as their inspiration. We've already seen the Big Dipper. To come later in the year are the Winter Circle, the Coat-hanger, the Summer Triangle and the Great Square of Pegasus. However, just like the stars of the Big Dipper and Sirius, Orion's Belt isn't what it appears to be.

Orion's Belt: The Great Illusion

Our view of Orion's Belt, three distant stars all lined up perfectly, is by pure coincidence, the kind of celestial accident that makes stargazing so beguiling—and so misleading. The Belt itself is sloped, with (from left to right) Alnitak the lowest, Alnilam in the middle and Mintaka highest. Alnitak is 800 light years from us, Alnilam 1300 light years, and Mintaka 900 light years. Alnilam is much bigger than the other two and, despite it being much further away, looks brighter. But look at those numbers again: while it's 800 light years to Alnitak, it's a good 500 light years from there to Alnilam. The stars in Orion's Belt have very little to do with each other—there is no Belt!

The Moon

Although many people learn to identify constellations like the Big Dipper and Orion in their childhood, it's the Moon that's frequently responsible for stargazers' fascination with the night sky.

Naked Eye Target: The Moon

Next time you stargaze, have a look at the Moon (Fig. 1.12). It may be below the horizon and out of view, or it may be dominating everything and making it difficult to find stars. Either way, if you can see it, note where it is in

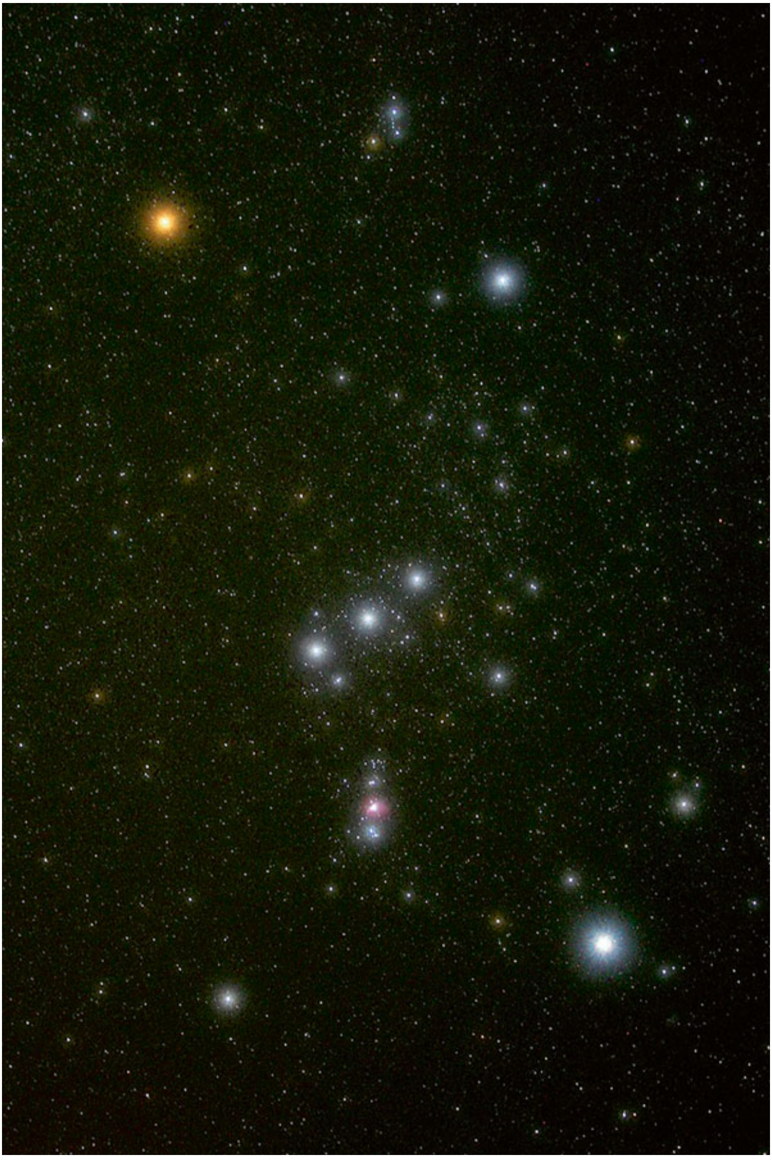

Fig. 1.10 The constellation of Orion. Credit: NASA

Fig. 1.11 The stars of Orion's Belt are many hundreds of light years apart

Fig. 1.12 The Moon rises about 50 minutes earlier each day. Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio

the sky, how it's lit (it may be a slim crescent, half-lit, or completely illuminated), and how bright it is. Try to look at it at the same time of night for three or four nights in a row and you'll get a snapshot of how it moves through the sky. Though it rises in the east and sets in the west just like anything else in the night sky because of Earth's rotation, the Moon's 29.5-day orbit of Earth is going in the opposite direction. Consequently, it appears to be in a slightly more easterly position in the night sky each night. It sets 50 minutes later in the west each night until it becomes Full, before rising 50 minutes later until it's New—and that's its orbit complete.

References

Couper, Heather & Henbest, Nigel. Stargazing 2014. Philip's, London. 2014.

CHAPTER 2

FEBRUARY: SOAKED IN STARS

The Stars of February

The stargazing activities this month will involve a lot of what we learned last month. A great way to learn the major constellations and track the seasonal changes in the night sky is to reinforce what you already know each time you begin a stargazing session. So next time you go out, try to star hop from Merak and Dubhe in the Big Dipper, to Polaris (see Chap. 1) and make that the first thing you do each time you stargaze. This habit will serve you well, particularly if you begin to stargaze from places other than where you normally observe from. Learning the night sky is easy; once you've found some familiar constellations and got your bearings, then try to identify a new constellation. This month we have the stars of the Winter Circle—some of the brightest in the night sky—our first star clusters, and the fabulous Orion Nebula. If you spend some time reinforcing what you've previously learned every time you stargaze, you will soon build up an awesome knowledge (Fig. 2.1).

Sidewalk Stargazing

Stargazing is all about learning to recognize constellations, key stars and phases of the Moon just by glancing up at the sky. When you see a star on the horizon, you'll be able to say, "That's Sirius," without a second thought. It's actually very easy to do.

Even if your good intentions to stargaze get waylaid by social engagements and the general business of life, there is a great way of reinforcing what you've already learned. Whenever you find yourself outside in the hours of darkness—perhaps when you're walking through a city or in a parking lot—look up at the night sky and try to find one or two of the constellations you've already learned. This can be quite tricky at first because you may be

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_2

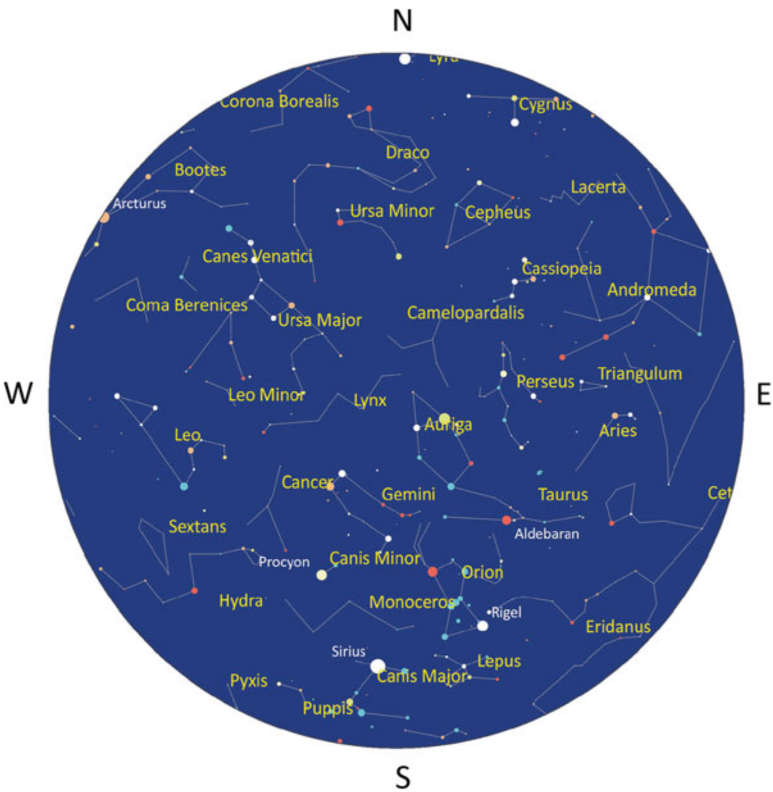

Fig. 2.1 Star-chart for February 1 at 10 p.m.

stargazing much earlier or later than you have been so far, when the stars have shifted their position. You'll also lack the visual clues that come from stargazing in familiar surroundings. For example, no longer will Orion be above your house, or the Big Dipper at the end of your backyard; you'll have to search for them. To do so is great practice at reinforcing what you know, but this is also where the star-hopping technique really comes into its own.

If you can find Polaris in any night sky (see Chap. 1), whether in the middle of an urban area or in remote rural surroundings, you'll always know where north is. Simple sidewalk stargazing like this only takes a few seconds or minutes, but it's not just north we're interested in. The same applies to the other side of the sky, which we'll explore this month.

Idle Stargazing

Repeating to yourself "wow, look at all those stars!" is not going to keep you entertained for very long, which is why you need an observing list each time your stargaze. Use the naked eye targets in this book as something to aim for; if you can go outside for 25 minutes and find a new constellation, or perhaps two, that's a great session. There's no need to rush. But heading outside with no idea of what you want to achieve is a sure-fire way of losing all enthusiasm, especially if it's cold.

The Rhythms of the Cosmos

The night sky works like clockwork. It always has and it always will. For untold centuries the night sky, the Moon and the Sun told farmers when to plant and harvest crops, guided mariners across vast oceans, and informed cultures and religions of the exact dates of festivals and ceremonies. To some extent, they still do. Our concept of a day, a month, and a year all come from the celestial mechanics of the Earth, Moon and Sun, respectively; how we organize our lives is a direct consequence of the changing rhythms of the sky.

However, over time we've tried to overcome the inconveniences of the exact length of orbits; a month lasts slightly longer than one Moon orbit (29.5 days), and the leap year exists to round-down the 365.24 days it takes for Earth to orbit the Sun. No longer does darkness descend at sunset; lights are switched on and life continues despite the rhythms of the night sky.

To stargaze is to return, albeit briefly, to these natural rhythms. Astronomy is often thought of as on the cutting-edge of science, but stargazing represents something much more ancient. Get to know the night sky and its rhythms, and you will soon discover an ancient calendar that remains unknown to most people.

Next time your friends and family invite you to dinner or a weekend away, don't look in your diary for scheduled events or sporting events. Go look at a celestial calendar, a lunar calendar and a weather forecast; if clear skies

are predicted, the Moon isn't going to be in the sky, or there's to be a meteor shower, you will know how busy you are going to be. This natural calendar will soon be yours to consult.

The Universe in Your Hands

Astronomers use math and calculations to find their way around the night sky, but stargazers can take matters into their own hands. It helps to know in basic terms how the night sky is divided up and charted, but actually finding your way around requires nothing more than outstretched fingers, hands and fists. It's remarkably easy.

The Celestial Sphere

In observing where the Sun rises and sets (Chap. 1), we've already begun to interpret the night sky as a dome. From one horizon to another is 180°, and from one horizon to straight above to your head—referred to as the zenith on star-charts—is therefore 90°. Easy. If something is 45° above the eastern horizon, for example, you face east and look at the midway point between the horizon and the zenith. Measuring smaller, less obvious distances—typically so you can star-hop from one place to another accurately—might seem like impossible guesswork. Luckily, humans are built for making measurements in the skies above in a quite remarkable way.

Hands in the Air

Humans are built to scale. A tall person will have longer arms than a short person. Their fingers and the size of their hands will also be of relative size. The effect is simple: anyone can hold out an outstretched arm and make simple measurements in the night sky using their just their fingers and hands. Here's how (Table 2.1).

Table 2.1 Measuring the night sky

1°	The tip of a finger
5°	The width of your three middle fingers
10°	The width of your fist
20°	The distance from the tip of your thumb to your little finger when you fan your fingers and hold out your hand

Fig. 2.2 The Moon may appear large in the sky, but it's possible to cover it completely with an outstretched finger-tip. Credit: NASA

Activity: Measure the Moon

It often dominates the night sky, but how big is the Moon? In relative terms to the entire night sky, it's tiny, as you can see if you measure its width with your fingers. Next time you see the Moon (Fig. 2.2), stretch your arm out and try to cover it with the tip of a finger. It's not hard to do, but confirms the width of the Moon as barely 1°. The Sun, too, can be covered by the tip

of a finger. It is only by chance that the Sun appears to be the same size in the sky as the Moon. Though the Sun is 400 times bigger than the Moon, it's also 400 times further away, which is why we can experience a total solar eclipse (Chap. 14).

Now try to measure how many degrees above the horizon the Moon is using your hands. The presence of mountains or buildings might mean you have to make an educated guess as to where exactly the horizon is, but you'll get a result that's accurate enough.

Calculate Your Latitude

Your latitude is crucial to what you'll see while stargazing. But how many people actually check their exact latitude on a world map? There's no need; you can do it with your hands.

Since Polaris lies at the north celestial pole, directly below it is actual north on Earth. However, it's the exact height of Polaris above the northern horizon that gives away your latitude. Stand a few degrees just north of the equator and Polaris will be visible a few degrees above the horizon. Stand on the north pole and Polaris will always be 90° above the horizon–directly above you. For any point in between, you can measure your approximate latitude using just your hands and fists (see above). If you stargaze from one place, you only need to do this once, but if you travel across the globe looking for darker skies, measuring your latitude north or south of the equator is a good habit to get into.

The Winter Circle

Having identified some of the brightest stars and most prominent constellations in the east and south during January, it's time to put all those pieces of the jigsaw together and find an enormous asterism, the Winter Circle. This giant asterism joins up the dots to create one huge shape, which also known as the Great Loop.

There are seven stars that make up the six points of the Winter Circle, most of which are relatively close neighbors of our Sun. Begin at Sirius, the lowest star of the asterism, and rising in the south, then move clock-wise. Use your fists to check that you've arrived at the right constituent star until you return to Sirius.

Naked Eye Target: The Winter Circle

The Winter Circle joins five of the brightest 15 stars in the entire night sky (Fig. 2.3). It's therefore possible to see the Winter Circle stars from almost any place on Earth, even a heavily light-polluted city.

Picking out the Winter Circle can give you an excellent wide-eyed view of the night skies, but there are some bonus features either side of its right-hand boundary. Outside the boundary, just beyond Aldebaran, is a sparkling star cluster, the Pleiades (pronounced 'player-deeze'), while inside lies the complete constellation of Orion, with its giant red star Betelgeuse (the ninth-brightest and one of the largest known stars in the night sky) just off the center of the Winter Circle. We'll visit both of these awesome sights shortly. The Sun—the brightest star of all in our sky—lies near the center of the Winter Circle in June.

The Sky in 3D

The Winter Circle is a line-of-sight asterism, an apparition in the night sky. Once you've got its huge arc in your gaze, consider how far the stars are, and try to push them back or bring them forward to see the night sky in 3D. Luckily, it's easy to do because there's a clear division in the asterism's basic shape (Table 2.2).

To see the Winter Circle stars as they really are, keep the top half as the middle section, in terms of distance. Then pull Procyon and Sirius—both near neighbors to the solar system and next to each other in the left-hand corner of the Winter Circle—forward in your mind's eye, and send distant Rigel way, way to the back. For the first time you're seeing the stars'

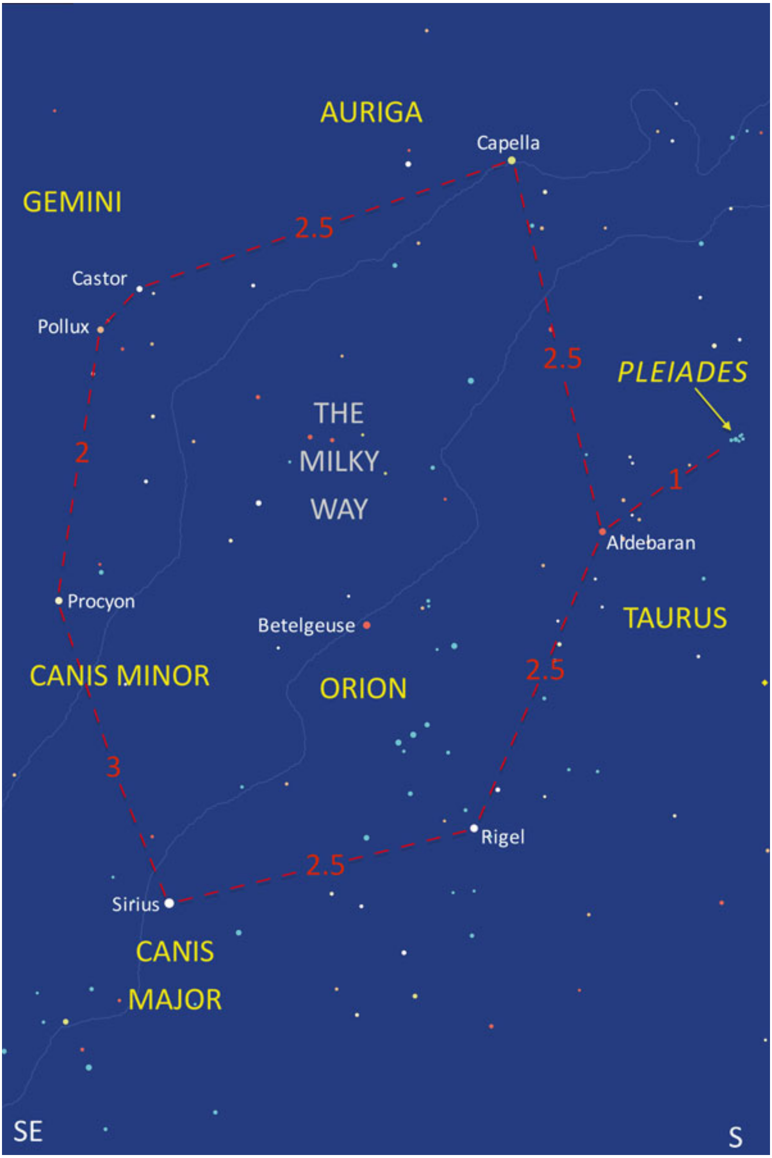

Fig. 2.3 The huge Winter Circle asterism groups together the brightest, most dominant stars of the season. Numbers in red refer to how many outstretched fists can be placed between each star.

Table 2.2 The distance from Earth of the Winter Circle stars

Sirius in Canis Major	8.5 light years
Rigel in Orion	800 light years
Aldebaran in Taurus	65 light years
Capella in Auriga	42 light years
Castor and Pollux in Gemini	50 and 34 light years
Procyon in Canis Minor	11 light years

positions as they really are. While it's difficult to consider distances of multiple stars at once, there's an easy way to get an impression of depth in the night sky: find the interloper. In this case, it's Rigel at 800 light years. Later in the year we'll look at the Winter Circle once again, but instead of distance, we'll think about the ages of the stars (Chap. 12).

The Milky Way

February is a great time to get a view of part of our own galaxy. The Milky Way runs right through the Winter Circle, from the top at Capella right down to the horizon between Sirius and Procyon. The Milky Way is only visible high above the heads of stargazers for two short periods of the year (high winter and high summer in the northern hemisphere) and January-March is the very best time to see it. This is the Orion Arm of the Milky Way.

Naked Eye Target: The Orion Arm of the Milky Way

We live in a spiral galaxy that has a number of spiral arms where stars have formed. What we know about our own galaxy is limited; since we live within it, we can only see parts of it. However, astronomers believe there are four spiral arms, one of which is our home, the Orion Arm. In winter we're looking outwards at the rest of it, away from the center of the Milky Way. Every single one of the stars in the Winter Circle is also part of the Orion Arm.

Sadly, since this is the slimmer, fainter part of the Milky Way with fewer stars, you'll only see it if you're in an extremely dark location. If you're in a dark place, give yourself at least 30 minutes outdoors before the concentrated

light from millions of distant stars begins to become visible. By April the Winter Circle is sinking in the west at dusk and the Milky Way is lost in the haze of the horizon, but there's much more to see come summer (Chap. 7).

Serene Stargazing

Don't get stressed about the stars. The downside of stargazing in winter is that you may not have a clear night for weeks on end. Considering the clarity of the stars during January, bad weather can be incredibly frustrating, but perhaps coping with disappointment is part of why stargazing is said to be good for your temperament.

Stargazing is a hobby that's entirely weather-dependent, and it's best to stick to properly clear nights. Although it is possible to spot individual stars, planets and the Moon between the clouds, the real wonder of stargazing—especially at the beginning—is the wide-eyed view of the cosmos that you can only really get under totally clear skies.

Sit Back and Relax

If you spend 30 minutes outside in the cold staring up at the zenith, you're going to wake up the next day with a sore neck. That's enough to put anyone off stargazing for good. One solution is to look at constellations much lower in the sky nearer to the horizon, but this isn't always a workable idea. Since there's a lot more light near the horizon, stars appear much dimmer and are often invisible. If you look at a constellation near the horizon, you're also looking through much more of the Earth's atmosphere, which doesn't help with clarity. In contrast, the constellations and stars directly above your head are in the absolute darkest part of the sky.

The simple answer is to sit in a deckchair or some other kind of garden furniture that's both comfortable and allows you to lean back easily. Doing so is also a great way of appreciating the wide-eyed view, though there are also a few practical considerations. Since it's winter, you're unlikely to have your garden furniture outdoors. Instead of having to delve into cupboards or garages, it's helpful to have a collapsed deckchair stored neatly near the back door that's easy to extract at a moment's notice.

Around the Winter Circle

After finding your way from star to star in the Winter Circle using just your fists, you can now easily get yourself to other well-known constellations, stars and star clusters.

Star-hop: Bellatrix to Aldebaran and the Pleiades

There are two bright stars above Orion's Belt; Betelgeuse on the left, and Bellatrix on the right (Fig. 2.4). Trace an imaginary line from Bellatrix going up and to the right. The angle is almost the same as that created by Orion's Belt. The first bright star you come to is Aldebaran in the constellation of Taurus. Go the same distance again and you'll come to the Pleiades; you've just made the most important journey in your stargazing career thus far.

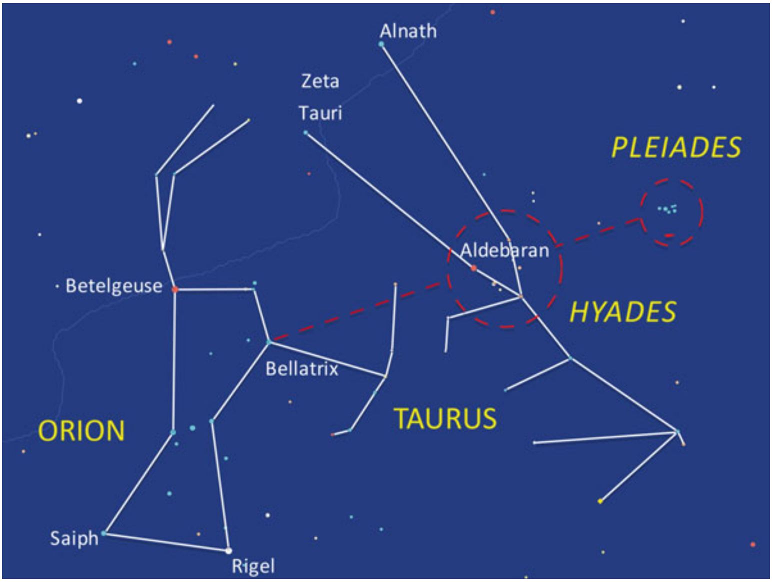

Fig. 2.4 Star-hopping from Orion through Taurus to the Hyades and the Pleiades

Fig. 2.5 The Pleiades (M45) in Taurus is a spectacular naked eye star cluster. Credit: ESO/S. Brunier

Naked Eye Target: The Pleiades, M45

A sparkling star cluster and one of the jewels of the winter sky, the Pleiades (Fig. 2.5) is your first open cluster, and your new favorite night sky sight. Around 440 light years from us and 100 million years old—almost a newborn in cosmic terms—the Pleiades is a young star cluster. The Pleiades is commonly known as the Seven Sisters because about seven stars can be seen with the naked eye. That tells its own story about our ancestors—either they had darker skies, or better eyes! You should be able to make out about five or six stars with the naked eye, especially if you look just to the side of it rather than straight at it. It looks like a baby Big Dipper.

What Is an Open Cluster?

An *open cluster* contains the building blocks of galaxies. Stars form when giant molecular clouds collapse under the force of their own gravity. This happens en masse, resulting in an 'open' cluster of hundreds or thousands of stars, which move together in a galaxy until, slowly, these stars disperse. In the Milky Way, there are countless star clusters, but the Pleiades is surely the most beautiful.

Naked Eye Target: The Hyades Open Cluster

Much closer to us than the Pleiades (and in fact the closest open cluster of stars to our solar system at a mere 150 light years distant), the Hyades is too big to look at with telescopes and even binoculars. It covers a much wider area of the sky than the Pleiades and is easy to find; just locate bright orange star Aldebaran, and trace a V-shape of stars pointing to the West (Fig. 2.4). At just 65 light years distant, Aldebaran is not in the Hyades, but in front of it, and so presents another easy way to see the night sky in 3D. Aldebaran is bright enough to be easily visible even during a Full Moon.

Naked Eye Constellation: Taurus

A well-known sign of the zodiac (more on these in Chap. 6) and a staple of the winter sky, you've already seen the highlights of Taurus: Aldebaran, the Hyades and the Pleiades. Orange giant Aldebaran is the eye of the bull on the top-left of the V-shape of the Hyades (Fig. 2.4), while the horns of the bull stretch above to two stars, Zeta Tauri and Alnath, above Orion. The latter star is shared with the constellation of Auriga (Chap. 3).

Orion, the Stepping Stone

Although we met Orion last month, it's so central in both stargazing lore and basic navigation at this time of year that it's worth spending (a lot) more time with this constellation. First let's look at how Orion can be used to find other significant stars and constellations in the night sky, many of which also help make up the giant Winter Circle asterism.

Naked Eye Target: Betelgeuse, the Supergiant

The second brightest star in the constellation of Orion after Rigel is Betelgeuse (some pronounce it beetle-juice, others bet-all-gerz), and it can be found easily; locate Orion's Belt, then look upwards from the left-hand star Alnitak (Fig. 2.4). Before you decide that it's just a star like any other, look at Betelgeuse again. Study it and the bright stars around it. Let your eyes glance at Betelgeuse, and scan quickly across it. You'll notice that while the other stars are white, Betelgeuse has an orange tinge to it. Betelgeuse is a red supergiant star (though its looks orange, never red) around 640 light years distant, and it's one of the biggest stars known to us at around 700 times the size of our Sun. If Betelgeuse was where the Sun is in our solar system, its radius would stretch way past the orbit of Jupiter, completely obliterating Earth. Aldebaran in Taurus (Fig. 2.4) also looks orange, and while it's smaller than Betelgeuse, its radius would still reach to the orbit of Mercury in our solar system.

Naked Eye Target: The Winter Triangle

Since the behemoth that is Betelgeuse doesn't get a starring role in the Winter Circle, there's a consolation prize in the form of this much smaller asterism, which is a much more rigid shape—it's almost an exact equilateral triangle (Fig. 2.6). Its three constituent stars—Sirius, Procyon and Betelgeuse—are the brightest, eighth brightest and tenth brightest in the entire night sky, respectively. Find Sirius (Chap. 2), locate Betelgeuse, then range left to make an equilateral triangle with Procyon (pronounced pro-see-on).

Betelgeuse: The Next Supernova?

The Sun isn't always the only star that's visible during daylight. Very occasionally a star explodes and is visible by day and night for weeks on end. Don't get excited, though—the last one was visible in 1604 when a star in the summer constellation of Ophiuchus (Chap. 6) suffered a supernova explosion. Supergiant star Betelgeuse is often predicted to be the next star

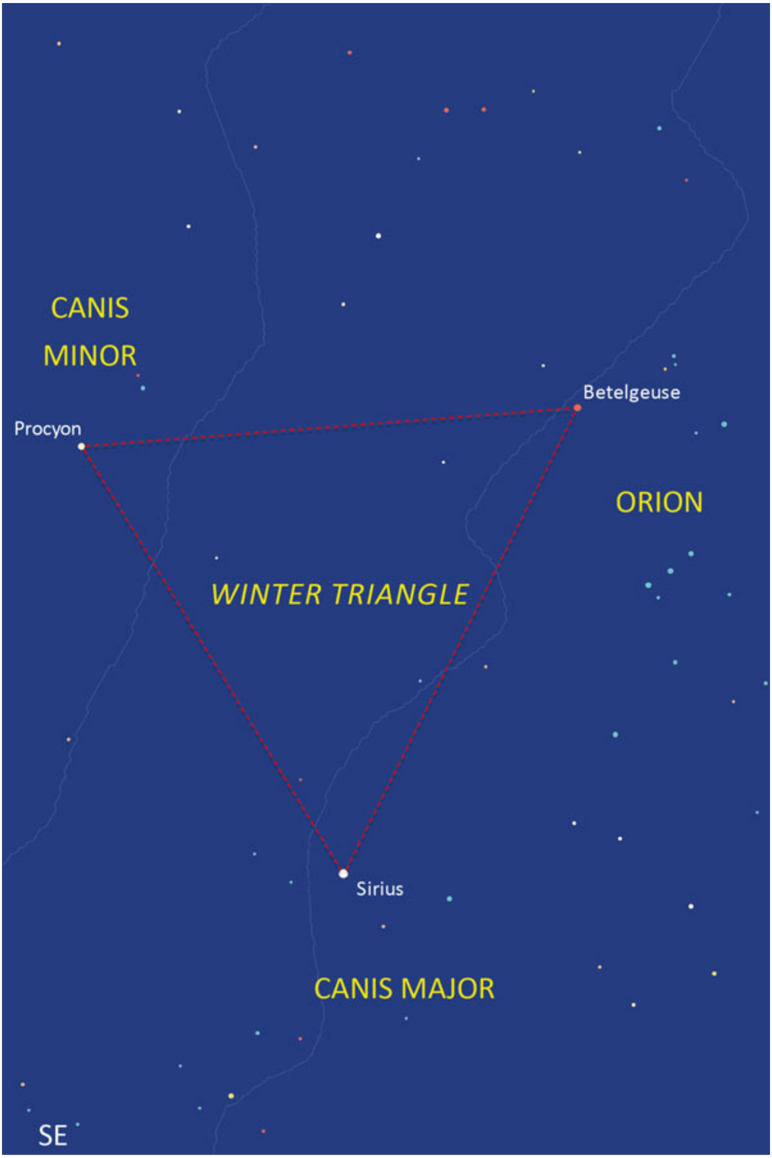

Fig. 2.6 The Winter Triangle includes bright stars Sirius, Procyon and Betelgeuse

to go supernova. Massive stars burn up their fuel much faster than smaller stars (such as our Sun), and as the core collapses, there's a huge explosion. Betelgeuse could go supernova at any time, though it's at such a distance that it may have already happened; as it is 642 light years from us, it could have exploded 642 years ago. If that's the case, it will look like it's going supernova any minute now … though it could just as easily take a million years.

The Supernova Six

Although Betelgeuse gets a lot of attention, the chances of it going supernova in the lifetime of humanity—let alone that of a single person—are tiny. Luckily, there are plenty of other candidates for a tantalizing supernova event that would be the unbeatable highlight of your stargazing career. No supernova candidate is close enough to the solar system for its explosion to cause us any problems; the safety boundary is reckoned to be about 50 light years.[1] Considering there are plenty of stars closer than that to the solar system, we're fortunate, since being struck by a supernova explosion would be a sticky end.

Many of the prime candidates to go supernova are too far away to see with the naked eye, but here are six nearing the end of their life that you can find in the night sky. Keep an eye on them; it may be that they have already exploded spectacularly, and we're just waiting to find out (Table 2.3).

Table 2.3 Supernova candidates visible in the night sky

Star	Distance in light years	Best seen from
Betelguese in Orion	642	December-April
Rigel in Orion	800	December-April (Fig. 2.4)
Spica in Virgo	260	April-June (see Chap. 4)
Deneb in Cygnus	1425	May-December (see Chap. 6)
Antares in Scorpius	550	May-July (see Chap. 7)
Eta Carinae in Carina	7500	Only visible from the southern hemisphere (see Chap. 13)

[1] http://www.nasa.gov/topics/earth/features/2012-supernova.html

The Color of Stars

To the human eye, the night sky looks largely black and white. Aside from a peppering of stars that have an orangey tinge (though only if you look carefully), stars look the same—but they're not.

Naked Eye Target: Rigel

If there's one star that really sticks out in the Winter Circle, it's Rigel at the bottom-left of the constellation of Orion (Fig. 2.4). Not only is this huge bright star a whopping 800 light years distant (far further away than any other in the asterism) and a candidate for going supernova, but if you look at it carefully you'll notice its bluish color. Scan from Rigel to Betelgeuse and back and it becomes obvious; stars do have color.

Sizing-up the Circle

Stars change color depending on their temperature, which in turn depends on their mass. The most massive, hottest stars are blue. The archetypal blue supergiant is Rigel. The coolest are orange, such as Betelgeuse (Chap. 2) and Antares in Scorpius (Chap. 7). Those in between are yellow; our Sun falls into this category (Chap. 8).

Betelgeuse and Rigel might be on the verge of destruction because of their massive size, but the other stars in the Winter Circle (Fig. 2.3) region are hardly small. In fact, there's not a single star among the seven that is as small as our Sun. Sirius, Procyon, Castor and Pollux are all around twice the diameter of the Sun, while Capella is 10 times the size, Aldebaran 44 times the size and Rigel a massive 70 times the size.

The Orion Nebula

There's much more to the sparkling constellation of Orion than Rigel, Betelgeuse and the Belt (Chap. 1). We've saved the very best for last; the spectacularly conspicuous Orion Nebula, surely the most glamorous sight in the entire night sky. This is where stars are born, and much of what astronomers know about star birth comes from studying this area of the sky.[2]

Naked Eye Target: The Orion Nebula

Look at Orion's Belt, then take your gaze slightly below; you have probably already noticed there's something darting downwards and at a slight angle. It's known as Orion's Sword, which appears to the naked eye to be made up from three stars, with a central star looking more like a misty patch. This is the Orion Nebula, a cloud of gas and dust around 1,270 light years away that's lit up by stars within it. It looks to be around the same size as the Moon.

The cosmic gas and dust in the Orion Nebula is coalescing to form massive, hot, young brown dwarf stars only a million years old (that's nothing in cosmic terms), and it's possible to see four of them in what's known as the Trapezium open cluster at the very center. However, to see such detail you will need optical aids such as binoculars and telescopes, which we will return to later in the year (more on these in Chaps. 4 and 9). For now, just bask in the glory of it as one of the most impressive naked eye sites in the heavens. To appreciate just how bright the Orion Nebulas is, look slightly away from it and catch it in the corner of your vision (just as we did with the Pleiades). It's positively glowing.

Nebulas and Star Clusters

Nebulas are one stage in the circle of life in the Universe. They are areas of cosmic gas and dust that either cause stars to be born, or are the result of stars dying. The Orion Nebula is very young, and still creating stars. As it

[2] http://www.cfht.hawaii.edu/en/news/Orion/

grows older, star birth will lessen and it will begin to resemble a tight cluster like the Pleiades. Its stars will then spread out, as has happened with the much older Hyades. Eventually, the stars born in the Orion Nebula will disperse completely and drift, apparently alone, in the cosmos. Our Sun is at that stage now; its origins are hidden from us. All stars come from clusters, and before that, from a nebula. So when you stargaze at the Orion Nebula, you're looking at a place very similar to where the Sun was born.

Light Speed, Distance and Deep Time

To stargaze is to look far back into history. Such are the distances between our Sun and all the other stars that the way we measure distance on Earth ceases to have meaning in the night sky. To appreciate how far away a star is, we have to think not in terms of distance, but time, specifically how long light takes to travel. So vast is the Milky Way that distance must be phrased as a light year; miles and kilometers just don't cut it. Nothing moves faster than light—it travels at a touch under 300,000 kilometers per second—yet it takes 100,000 light years to cross from one side of the Milky Way to the other.

All Starlight is Old Light

Every single star you look at in the night sky may be dead, defunct, exploded and gone. Even the nearest star to our solar system, Proxima Centauri (Chap. 13), could have exploded 4.2 years ago and we would be none the wiser. Similarly, light from Sirius—just 8.6 light years from us and the nearest star we can see from the northern hemisphere—started its journey 8.6 years ago. Cosmically speaking, these two stars are our close neighbors. The math is not complicated, but it is profoundly shocking if you've never considered it before since it makes traveling outside of our solar system a hopeless task.

The Way Things Were

What you see in the night sky is a snapshot of how things were, at random times in the past. You could say quite logically that the night sky, as you see it, does not exist and has never existed. However, the night sky is not timeless and unchanging. The closest stars do shift slightly—enough for detailed star atlases to be redrawn periodically—and yet, in multiple human life-times the night sky barely changes at all.

Deep Time

Though time isn't as difficult to express as distance, the night sky operates on a time-scale that's hard to comprehend. Astronomers using powerful telescopes like the Hubble Space Telescope (see Chap. 12) can look back into deep time by capturing images of galaxies over 13 billion light years away, which is only 'a few hundred million' light years after the Big Bang created the Universe. Are those galaxies actually still there? It's impossible to know—they could have only lasted a few million years—but their light is only now reaching us. If that kind of scale is just unfathomable, try this one; the light from the Andromeda galaxy, which is best viewed in October (more on this in Chap. 10), was produced 2.5 million years ago as the first, distant ancestors of humans were beginning to use tools in Africa. Yet this is merely the galaxy next door; in the Universe just as within our own galaxy, distance and time are intertwined.

The Age of Everything

Despite the time-scales involved, with a few constants in your head it is possible to make simple comparisons. This is best done by comparing everything to what we know best: our own Sun, the solar system, and the Milky Way. For instance, reading that million-year-old stars in the Pleiades are young only makes sense if you know that the age of our Sun is over four billion years (Table 2.4).

Table 2.4 The age of the Universe

Object	Age
Universe	13.82 billion years
Milky Way galaxy	13.2 billion years
Andromeda galaxy	9 billion years
Sun	4.6 billion years
Earth	4.54 billion years
The Pleiades	100 million years
Orion Nebula	3 million years
Human species	200,000 years

Where Are We?

Our solar system is 27,000 light years from the supermassive black hole at the center of our Milky Way galaxy, which spans 100,000 light years across. Our Sun is one of 300 billion stars inside of it (Space.com 2013). Some galaxies are visible to the naked eye, and dozens more with a small telescope. Telescopes like Hubble can see thousands upon thousands of other galaxies, some of which are so far away that the light has taken 13 billion years to reach us, almost back to the dawn of time itself. There are around 225 billion of these galaxies in the known Universe (Temming 2014).

Stargazing Apps

Like everything to do with smartphones and tablets, the temptation of having an instant stargazing guide is hard to resist. Not only are many of these apps free, but these augmented reality planetarium apps will tell you exactly where various stars, constellations and planets are. Where's Sirius? What's that star near the horizon? Are there any planets in the night sky tonight? With a little help from your smartphone, these and other questions become easy to answer as you find your bearings and transform your understanding of Earth's ever-changing view of the solar system and beyond. Hold your phone up to the sky and your smartphone's compass and accelerometer will present a 'live' view of exactly what's in front of you.

So what's the catch? Finding something only on your phone's screen means nothing. Successful stargazing is finding most of the major constellations in the sky at any time of the night or year without any technology to help you, and to know what's due to rise soon.

Using Smartphone Apps

Proceed with care. While you might go out stargazing with the best of intentions, the moment you take that smartphone out of your pockets it's unlikely to go back in, and you may well spend the rest of your stargazing session staring at your phone instead of at the night sky.

A few years ago I was on a beach in Queensland, Australia waiting for a total solar eclipse with about 2000 other people. As we waited for dawn to break, the sparkling Southern Cross constellation (Chap. 13) hung above the horizon in front of us. A woman near to me was holding a tablet in her hand and pointing at, it saying to her friend: "Look! There's the Southern Cross! I've always wanted to see that!", but she wasn't seeing it at all. She was staring at her phone's screen, and pointing at a graphical representation of the Southern Cross. Not once did she look at the actual constellation. By staring at the screen instead of the night sky, she was conducting one of the strangest stargazing sessions I've ever seen; armchair astronomy without the armchair. Such is the obsession with smartphones and apps that it's quite common to see stargazing done this way. I won't pretend that I didn't use a stargazing app to find the Southern Cross myself a few nights earlier; the stars of the southern hemisphere were unknown to me at the time, and it was a great help. You should definitely download one to your phone. However, having identified where it was in the night sky, I spent the next few nights tracking it purely with my own eyes and a pair of binoculars. This is how you should use a smartphone app: to get your bearings and identify—just once or twice—constellations or stars that you have never seen before, and then put it away. Measure your progress by identifying stars without using an app, and at different times of night.

Choosing a Stargazing App

The best stargazing apps cost money. There are free apps, such as Google SkyMap,[3] that will show you the locations of major constellations, stars and planets, but that's about all they do. A good stargazing app will have a red light mode, so you can use it without destroying your night vision (see Chap. 1), though it's still wise to also turn the brightness down on your device. Good apps will also allow you to touch a star on the screen to find out more information (such as the size and distance from Earth), show you the rise and set times for the Sun, Moon and planets, include flight paths of major satellites, and be updated frequently to include passing comets that may be visible. A great basic option is The Night Sky,[4] which is available both as a smartphone app and for desktop computers, though planets do tend to be shown as much bigger and brighter than they actually are. For instance, it shows Neptune as a major object despite it being hugely challenging to find (more on this in Chap. 10).

Tracking the Live Sky

Since the planets move, and can easily look like bright stars, stargazing apps are invaluable for identifying them and tracking their progress. However, since most of the planets move slowly, once you've identified where they are you'll hopefully be able to spot them yourself while they remain in the night sky with no need for an app.

Sky Live[5] is a great app to have in your stargazing arsenal. It gives a useful stargazing-centric weather forecast for your location, which is updated every hour. As well as cloud and visibility predictions, it also includes the major sights up on any given night, as well as rise and set times for planets and even the International Space Station's (ISS) exact position (Chap. 5).

3 www.google.co.uk/mobile/skymap
4 http://www.icandiapps.com/icandiapps/night-sky-apps/
5 http://vitotechnology.com/sky-live.html

The makers of Sky Live also produce Star Walk,[6] which has a database of over 200,000 stars, planets, constellations, satellites and galaxies in the night sky. Navigating the night sky is easy because it tracks as you move your phone. It's also possible to interrupt it by pinching to zoom in, or dragging it to easily study a specific area of sky. It's also got a search box; enter the star or object you're looking for and it puts an arrow on the screen that points you in its direction until you've turned to face it. All this can be done in a red-light night-vision mode. Just as professional and available as both a smartphone app and as software for a desktop computer is SkySafari,[7] which also has a night mode. Most stargazers' laptops will have one of the free planetarium programs, too, such as Stellarium[8] or Cartes du Ciel,[9] which allow you to navigate the night sky, rewind and fast forward it, build observation lists, and print out star charts. As you get more experienced, they're invaluable, but don't make the mistake of spending hours learning how to use a new piece of software when you should be outside learning about the night sky.

Swapping Hemispheres

If you want to study the southern hemisphere stars (Chap. 13) without travelling, just point one of these apps at your feet. It sounds dumb, but it does help you see how restricted your view of the night sky always is. Stargazing can be done any time, anywhere, but it's best done in as wide a variety of places as possible. Although there's plenty of overlap in terms of stars and constellations, swapping hemispheres can be disorientating, and this when stargazing apps really come into their own.

However, anyone who has crossed the equator and tried to use one of these apps will know that they can go wrong. Some apps travel better than others; while they might work fine in your backyard, if you swap hemispheres (perhaps by going on vacation to Australia, South America or southern Africa) these apps often present the wrong horizon when you hold your phone up to the sky, which can be very confusing. It's often

[6] http://vitotechnology.com/star-walk-2-guide-sky-night-day.html
[7] http://skysafariastronomy.com/products/index.html
[8] www.stellarium.org
[9] www.ap-i.net/skychart/en/start

necessary to restart your phone, and perhaps even delete and re-download the app, until it gets an accurate fix on where you are. (This is best done over WiFi before you travel into remote areas.

A Cosmic Faux Pas?

While you may find yourself relying on a stargazing app to improve your knowledge (and that's fine if you use it sparingly) be careful using them around other stargazers. If you join a local astronomy club, you may be asked to switch off your phone, or at the very least turn the brightness down and engage a red light mode. It very much depends on who's in charge; I've been frowned at and asked to turn off my phone at some star parties and observatories, while at others, phones appear to be used at full brightness and with wild abandon. It's best to check, or to follow the lead of others. Either way, a protective drop-proof case for your phone (and especially for a tablet, if that's what you're using) is a must. Holding expensive gadgets above your head is asking for trouble.

The Moon in Motion

The Moon has an illuminating orbit. Our satellite is always on the move around Earth, and always half-lit by the Sun. From Earth it may look as if it's only slightly illuminated, or a quarter-lit, but this is just the portion that we can see from down here. People often talk (or sing) about the dark side of the Moon, but it doesn't exist; there is only a side we never see because the time it takes for the Moon to rotate once is exactly the same as the time it takes to orbit Earth once—about 28 days. The Moon's gravity causes tides in the Earth's oceans, but the gravity of the Earth keeps the Moon almost perfectly in-sync. But that unseen side is lit-up by the Sun just as much as the side we can see.

Naked Eye Target: The Full Moon

Who can resist the ethereal glow a Full Moon gives the night? Stargazers, that's who. Love the Moon you might, but when it's Full (Fig. 2.2) it's too

bright to look at, leaving stargazers dazzled and washing out all but the brightest of stars. It's best avoided, especially if you're headed for dark rural skies to stargaze. However annoying moonlight may be for stargazing, the sight of a Full Moon rising and setting is one of nature's greatest and least observed spectacles (more on this in Chap. 8).

References

SPACE.com Staff. 100 Billion Alien Planets Fill Our Milky Way Galaxy. [ONLINE] Available at: http://www.space.com. 2015. [Accessed 01 June 15].

Temming, Maria. How many galaxies are there in the universe? [ONLINE] Available at: http://www.skyandtelescope.com. [Accessed 01 June 15]. 2014.

CHAPTER 3

MARCH: THE PLANE TRUTH

The Stars of March

March is the month when spring begins, and one of the best months for stargazing. The way the Sun, the Moon and the planets move across the sky reveal what stargazers call the ecliptic; this is the flat plane of the solar system, and locating it in the night sky can give you a powerful sense of our place and position among the stars. March is also a great month to see planets; driving home from work or evening walks are accompanied by the sunset, and often the planets peeking-out at dusk. This month is also the vernal equinox, when night and day last 12 hours each. With spring comes new constellations, though why stick to the calendar? We'll learn how to see April and June's constellations in March, and watch how the Moon changes as it makes a complete orbit of our own planet.

The Ecliptic and Planet-Hunting

Those charts on classroom walls that place each planet in the order that they orbit aren't wrong, but the solar system isn't static. Planets move around the Sun at different speeds, but stargazers are lucky; we get to watch it all happen.

There are some simple rules for finding planets. Don't ever look to the north and speculate whether a bright star is a planet. It's far simpler than that. There's a line going from east to west across the night sky on which all planets are found. This is the plane of the solar system, and it is called the ecliptic.

Whether there are any planets viewable during the hours of night where you are as you read this is impossible to say, but maximizing your chances of glimpsing these wandering stars is easy.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_3

The Ecliptic

It's possible to see the plane of the solar system on every single clear night. On almost the exact line that the Sun appears to cross the sky during the day, so too the planets cross by night. This imaginary line is called the ecliptic, and it stretches from the point on the eastern horizon where the sun rises to that place where it sets in the west (Fig. 3.1). It's here—and only here—that you'll see planets during darkness. Exactly how high in the sky the ecliptic is depends on the time of year; since Earth's axis inclined by 23.5°, it appears to move with the seasons.

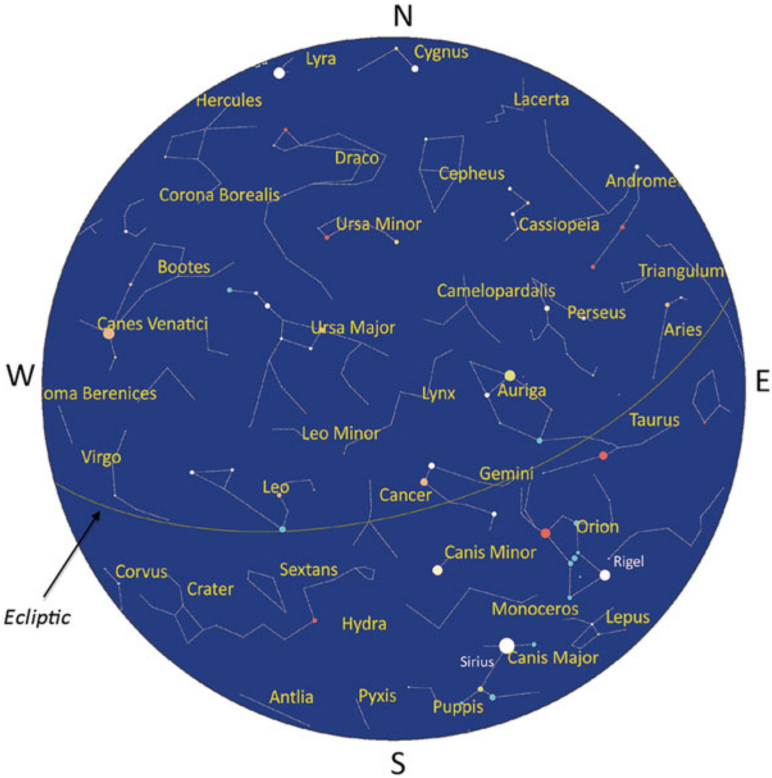

Fig. 3.1 Star-chart for March 1 at 10 p.m., with the ecliptic marked; the Sun and the outer planets appear to follow this line across the sky

The knowledge that the Sun's path across the sky is exactly the same as the Moon and the planets is simple, but will change your night sky navigation forever.

Astronomers aren't sure why planets orbit the Sun in the same, flat plane, but it could be to do with how the dust cloud that collapsed to form our Sun was rotating. The result was a flattened disk of dust, from which all the planets formed (Odenwald 1998).

The Visible Planets

You know how to find Polaris (Chap. 1), and hopefully locating it is one of the first things you do time you stargaze. Knowing how to find north is also useful when thinking about our point of view when we look at the night sky, and for finding planets. When you stargaze, you're not just staring out into space; you're looking in a very specific direction. As night falls, Earth has rotated enough for the Sun to no longer shine on where you are. Consequently, each time you stargaze you're looking at the outer solar system. You're looking backwards away from the Sun. In terms of planets, this greatly affects what you can see, and when.

Back in school you probably learned the positions and the order of the eight planets; nearest the Sun is Mercury, then Venus, Earth, Mars, Jupiter, Saturn, Neptune and Uranus. Pluto was relegated to the status of dwarf planet in 2006 and, besides, it's way too small to see with the naked eye. So too Neptune and Uranus; they're so far away and faint that you'll struggle to see them with your own eyes (Chap. 10). What you probably didn't learn is that although the length of the planets' orbits varies enormously (for example, Mercury goes around the Sun every 88 Earth days, while Saturn takes 29 Earth years to make one orbit), they all orbit the Sun in such a way that they are easy to spot.

How to Identify a Planet

Some people buy a newspaper each day because they like to know what's going on in the world, but stargazers are just as interested in knowing what's going on around it. Once you've identified which planet is

which—perhaps, initially, by using a star-chart or an app on your phone, or by buying an astronomy magazine that list that month's best observing targets—you can easily keep track of them. Since most of the planets orbit relatively slowly, they don't shift much from day to day. However, they appear to move across the night sky relatively quickly. This is because the Earth is also moving, and a lot faster than most of the planets.

Spring Constellations

March brings with it new constellations and celestial wonders. The sparkling stars of winter begin their dive down to the horizon just after sunset, and we bid farewell to Taurus, the Pleiades and Orion. This month we will find the constellation of Bootes rising in the east, but there is still time to get acquainted with the winter stars in the constellations of Auriga, Gemini and Canis Minor.

Star-hop: Arc to Arcturus

As with all the best signposts, we start with the Big Dipper. Move your eyes along the curved handle of the Big Dipper, and continue in the same curve until you get to a bright star (Fig. 3.2); this is Arcturus.

Naked Eye Target: Arcturus

High in the sky at the foot of the constellation of Bootes, the orange giant of Arcturus is a real heavyweight star. A red supergiant (look at it carefully and you'll notice its orangey color), Arcturus is the fourth brightest star overall after Sirius (Chap. 1) and two southern hemisphere stars, Alpha Centauri and Canopus (Chap. 13). Arcturus is huge. Just 37 light years distant, it's about 27 times larger than the Sun, though over 100 times brighter. Arcturus is also the brightest star in the constellation of Bootes (see below).

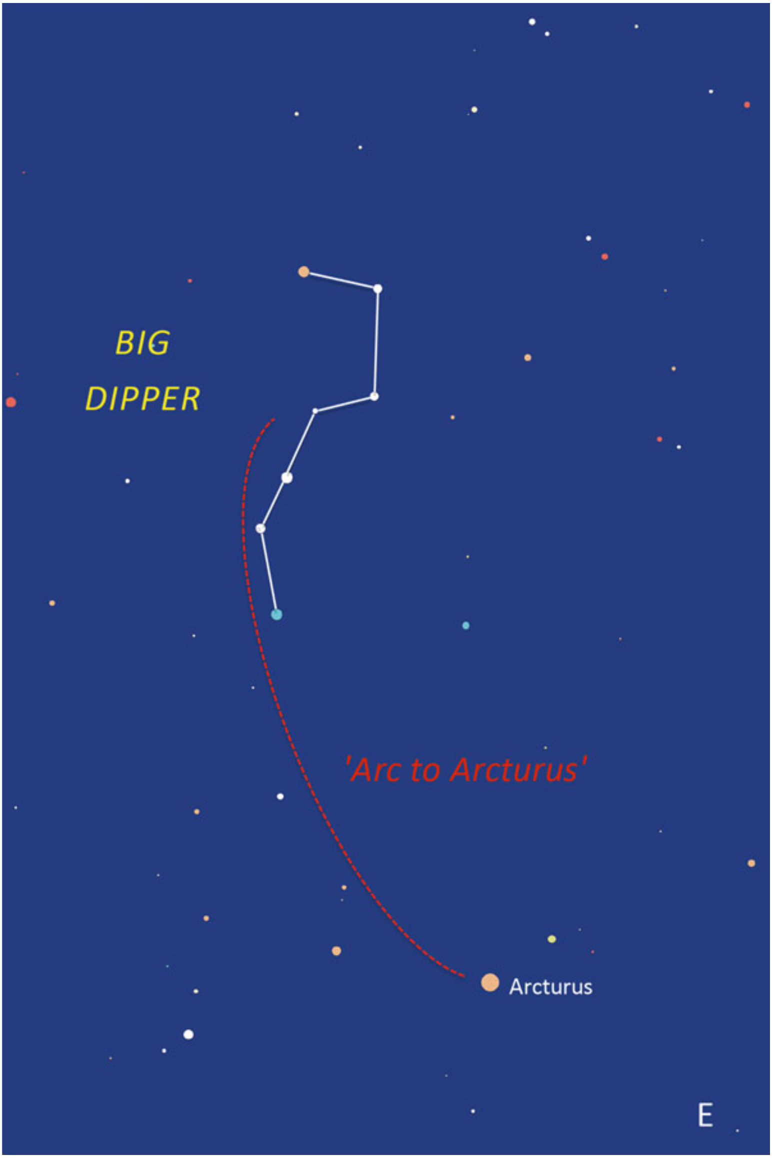

Fig. 3.2 Arc to Arcturus: an easy way of finding this orange star in spring and summer is from the Big Dipper

The Celestial Equator

This is nothing more than an imaginary line projected upwards from the Earth's equator into the night sky, essentially dividing it into the southern hemisphere stars and the northern hemisphere stars. If you stand on the equator, technically you can see all the stars in both hemispheres at some point during the year, though stars near the poles—such as Polaris and the other stars of Ursa Minor (Chap. 4) in the north, and the stars around the Southern Cross (or Crux) in the south (Chap. 13), will be very close to the horizon, so impossible to see. Conversely, if you stand at the north pole or the south pole, you will not see any stars beyond the celestial equator.

The Arcturus Stream

Arcturus is relatively close to us, but it's not moving around the Milky Way in the same direction as most of the stars. Instead it's moving perpendicularly through the Milky Way (Sessions and Byrd 2015) together with 52 or more stars that are significantly older than those surrounding them. These ancient relics are known as the Arcturus Stream, and they could be from a dwarf galaxy that crashed into the Milky Way long ago. Because of this motion, in around a million years Arcturus will be so far from Earth that it will no longer be visible to the naked eye (Sessions and Byrd 2015).

Naked Eye Constellation: Bootes

Rising in the east this month on its side and directly beneath the Big Dipper, and destined to hang in the night skies until fall, is the constellation of Bootes, the Herdsmen. Even when viewed from a dark sky, it looks more like an ice cream cone, or a kite. Beneath it is the beautiful constellation of Corona Borealis, but as it is so close to the horizon this month, it's worth finding it later in the year, when it's an absolute stunner (Chap. 6).

Naked Eye Constellation: Auriga

Now high in the south west sky above Taurus and between Perseus and Gemini, we've so far almost ignored the pentagon-shaped constellation of Auriga (Fig. 3.3). The star of the show here is the beautiful, bright orange Capella, which is in the Winter Circle (Chap. 2). Just below Capella are three dim stars that form a stretched triangle. They're known as The Kids.

Situated over the northern section of the Milky Way, Auriga contains three open clusters much like the Pleiades (Chap. 2) yet further away and no as obvious to the naked eye. They're called M36 (the Pinwheel Cluster), M37 (which despite having no proper name is the most impressive!) and M38 (the Starfish Cluster), all of which we'll return to in November (Chap. 11) with binoculars and a telescope.

Naked Eye Target: Capella

Although it's now about as high as it gets in the southern sky around 10 p.m., Capella's brightness makes it one of few stars—along with Vega in April (Chap. 4)—that can be visible just above the horizon when due north (Dunlop 2004) and, as such, has traditionally been used for navigation. A mere 42 light years distant, Capella (Fig. 3.3) is actually a binary star, though the two stars orbit each other so closely that only huge telescopes can split them.

Naked Eye Target: Procyon

You're properly wondering why we haven't looked at a constellation featuring Procyon, another star we used to find both the Winter Circle and the Winter Triangle (Chap. 2). Around 11 light years from our Sun, Procyon—Greek for 'before the dog' because of its rising before Sirius—is, like many stars in the night sky, a binary star system. Like Capella (above), it's a double star. Procyon is by far the brightest star in one of the least impressive naked eye constellations of all, Canis Minor, the small dog, which only has one other star in it, Gomeisa at 170 light years distant (Fig. 3.4).

Fig. 3.3 The constellation of Auriga includes three star clusters and a tiny triangular asterism called The Kids

Naked Eye Constellation: Gemini

Although a famous constellation because it's part of the zodiac (Chap. 6), you might have problems finding much of Gemini with the naked eye despite it being nearly overhead at this time of year. Gemini is known as the Heavenly Twins, and its two main bright stars is all you will easily see. The brightest star is Pollux and its close neighbor is the slightly dimmer Castor (Fig. 3.4). Once again, the latter is an illusion, being not one star but six through a telescope (Chap. 12). We'll return to Gemini with binoculars to have a look at a fine open cluster of stars called M35 (Chap. 12).

Naked Eye Target: Canis Major … and Felis Major?

With the Belt stars of Orion in your gaze, scan two fists towards the horizon to bright star Sirius, which is the primary star in the constellation of Canis Major, the Big Dog. Sirius doesn't get very high in the sky, so the other, less bright stars in Canis Major may be lost in the haze of the horizon. However, if you happen to be observing from about 30° latitude or thereabouts (Florida, Texas, the Canary Islands, North Africa or the Mid-East) you will have the chance to trace the pattern of a dog, but since bright Sirius marks its nose, it's all rather confusing. Perhaps it should be a reindeer. Much more obvious to my eyes is the shape of a cat; its face and front paws are made-up of the same stars in Canis Major that create the dog's hind quarters, with a few bright stars to the east (actually in the little-known constellation of Puppis) marking its back legs and tail (Fig. 3.5). If you can't see the constellation you're looking for, why not create your own?

Make Your Own Constellations

Constellations are purely about using your own (or someone else's) imagination, and they probably say more about the person who created them than about the night sky itself. For example, although Claudius Ptolemy codified 48 constellations back in the second century, another 40 have since been added, mostly in the southern hemisphere. One astronomer named the Sextans constellation in the southern hemisphere after the sextant he was using for his astronomical observations, while in 1874 Benjamin Gould

Fig. 3.4 The constellations of Gemini and Canis Minor

Fig. 3.5 Canis Major and the author's own constellation of 'Felis Major'

created Vela (the sail), Pyxis (the compass), Puppis (the stern), and Carina (the keel). Gould had worked for the US Coast Survey (Encyclopedia Britannica 2015), so also had boats and navigation on the brain.

If constellations were created from scratch now, they would probably not be named after gods, hunters, mythical animals and queens. Modern humans would likely find the shapes of familiar, everyday obsessions in the night sky, such as smartphones, aircraft, trains and cats (see above).

Expand Your Horizons

Most stargazing books and manuals recommend you observe from a location that has a clear view to the horizon, preferably to the east so you can see constellations rising. Good luck—unless you're in the business of climbing up mountains in the dark, it's likely that you're going to have trees and buildings blocking the horizon completely. Should you ditch your observing location in your backyard and head uphill? There is a simpler way; wait one month. By that time the constellations in question here—Bootes, Corona Borealis and Hercules—will be much higher in the eastern and southern sky at the same time of night in April. They will be brighter, too, because they're out of the haze of the horizon. Of course, having a low horizon to the west is great for that last-gasp glimpse of a constellation or object before it sinks and remains hidden for months. If you look to the west this month just after sunset you will see the Pleiades and the Hyades falling towards the horizon, followed by Orion (Chap. 1).

Naked Eye Target: Sunset

You've probably seen dozens of sunsets, but have you ever thought about what's happening to the stars? If you look west just after sunset when the stars come out, the stars you see closest to the horizon and edging towards its glare. In a month, they will become invisible.

However, the stars are merely the background. What's changing is our view of the Sun, which appears to shift eastwards in the sky as the year

progresses. Just as the Sun appears to move across stars, rendering them invisible to us, once it's passed over them those same stars become visible just before dawn. To stargaze is to witness the awesome clockwork of Earth's orbit around the Sun.

This month and next, have a look for the Pleiades just after sunset before it gets lost in the haze during May. Unless you're up well before dawn this summer, we'll see the Pleiades again in November (Chap. 11) when it announces the coming of Orion and the Winter Circle (Chap. 2).

The Four-Minute Map

If you've been stargazing at roughly the same time of day you probably noticed that the constellations and stars are changing their position at quite a pace. The reason is simple; as the Earth orbits the Sun we have a slightly different view of the heavens each night, although the difference is only four minutes in any 24 hour period.

Celestial Motion

The entire sky appears to shift forwards by four minutes each night. If you see Arcturus rise at 19:12 on March 15, it will rise at 19:08 the following day. Six months later, it will rise at 07:12 in the morning on September 15 (not allowing for daylight saving changes). If stars are rising four minutes earlier each night, it follows that they're always taking only 23 hours and 56 minutes to return to where they were the previous night. This is what astronomers call a sidereal (pronounced sid or side-ear-real) day.

Since everything shifts forwards by four minutes each day, star-charts move backwards. Four minutes may not seem like much of a difference, and you most likely won't notice it if you spend a few consecutive nights stargazing, but over the course of a month those daily four-minutes changes add up to about two hours. That's why most star-charts are accurate only for a two-hour window (Chap. 1) that gradually shifts backwards. The star-charts at the start of all of the chapters in this book work for 10 p.m. at the beginning of the month, and for 8 p.m. at the end of the month.

With a particularly cloudy month, and perhaps a few nights of observing missed on purpose because of the Full Moon, stargazing sessions can feel fleeting. If you're after a particular constellation, star or other night sky object, catch it while you can because it will be gone much quicker than you think.

The Dawn Raid

A great way of seeing how quickly the night sky can change is to look at the sky at a completely different time to when you've been observing so far. If you find yourself outdoors at 4 a.m. when you're usual stargazing time has been 10 p.m., the sky will have shifted so much that you may not recognize anything in the eastern sky—and everything you do know, such as Orion, the Pleiades and Sirius, will have sunk in the west. Constellations are tied to seasons only by the convention of what's overhead in the evening; what you actually see depends entirely on what time of night you stargaze. However, look to the north and you'll see the Big Dipper and Cassiopeia on either side of Polaris, although they will have swapped places compared to what you've seen so far this year (Fig. 2.4). This is a lesson in how the night sky works; by getting up at 4 a.m. early in March you'll see the same night sky that you would see at 10 p.m. in June. That's great if you just can't wait to get ahead and learn new constellations.

Not only are most of the circumpolar constellations visible at some point during the night all year round, but there are other stars nearby in the north celestial sphere that do become visible at some point on most nights, if you wait long enough, such as Capella (above), Vega (Chap. 5) and Deneb (Chap. 6).

Naked Eye Target: The Pre-dawn Sky

Try to get up at 4 a.m. this month for a sneak peek at the stars of June (Chap. 6), though if that's not likely, try staying up until 2 a.m. to see what stars we'll be looking at in May (Chap. 5). Obviously it's worth checking the weather forecast before making plans. Early-risers might also want to let others in the household know, as some people don't appreciate being woken up at 4 a.m. by someone rushing downstairs and opening doors. I have no idea why!

Understanding the Equinox

The vernal equinox happens in late March and heralds the start of spring. You may think it has little to do with stargazing, but understanding the equinox—which merely means 'equal night'—will help you put the seasonal changes in the night sky into a bigger context. Along with the fall or autumnal equinox in September (Chap. 9), it marks the point when the midday sun is directly above the equator, giving every location on the planet 12 hours of daylight and 12 hours of darkness. It also signifies the moment when the ecliptic crosses the celestial equator. Only on those two days of the year will the Sun rise exactly east, follow an arc right along the celestial equator, and set in the exact west direction (Strobel 2015).

The vernal equinox is also when the north pole at last sees some twilight after six months of darkness; between the equinoxes, the 23.5° tilt of Earth means that the Sun and, hence, the ecliptic, slips further north in summer. The maximum point is marked by the summer solstice (Chap. 6), which means the longest day, and therefore limited, but warm stargazing. After the fall equinox, the Sun appears to move further south, culminating in the winter solstice (Chap. 12), which means long, cold and clear nights for wrapping up warm and going outside with a star-chart.

Two Celestial Stomachs

Too huge animal constellations—Ursa Major the great bear, and Leo the lion—are visible this month, and both of these animals have bellies of real celestial significance. Ursa Major you already know (it's home to the Big Dipper), while Leo sits on a window looking out to the Universe beyond.

The Great Bear's Belly

You will be able to pick out the seven points of the Big Dipper (Chap. 1), the asterism that forms the bulk of Ursa Major. The rest of the stars that extend to form the giant constellation of Ursa Major are fainter, but

eyes that are dark-adapted should be able to find them even in light-polluted skies. Some cultures think it looks like a skunk (Chap. 15).

Naked Eye Constellation: Ursa Major

See the handle of the Big Dipper as the tail of the bear (Fig. 3.6), and look beyond those pointer stars, Dubhe and Merak, to find Muscida, then turn 90° until you hit a wide naked eye double star, Talitha and Talitha Australis. What a grand sight! Even better, it's the first of three easily visible double stars (none of which are true binary stars, they just look close from our position) in a row that mark the belly. As you move down towards the horizon you'll see Tania Borealis and Tania Australis, then Alula Borealis and Alula Australis. Finally, turn 120° back in the direction of the pointer stars, then take a 90° turn back to Alkaid at the tip of the bear's tail.

Concentration is needed, but finding Ursa Major and its treasure-trove of naked eye double stars is endlessly rewarding; you'll never look at the Big Dipper in the same way again.

The Realm of the Galaxies

Since galaxies are so distant and mostly impossible to see with the naked eye, you could argue that they have no place in stargazing. However, understanding what's beyond our view is crucial to understanding our perspective from inside the solar system. The stars appear to move across the night sky from east to west, but what's really happening is that our window on the Universe beyond shifts gradually. At this time of year, as the constellation of Leo rises, we're looking away from the center of our own galaxy and into deep space.

There are few stars in this region of the sky, and less to block our view of what's beyond our own galaxy. The area of sky just beyond the lion's tail at bright star Denebola (pronounced den-eb-oh-lar) and towards the constellations of Virgo and Coma Berenices (Chap. 5) is the Realm of the Galaxies, a cluster of distant galaxies far beyond the Milky Way (Fig. 3.7).

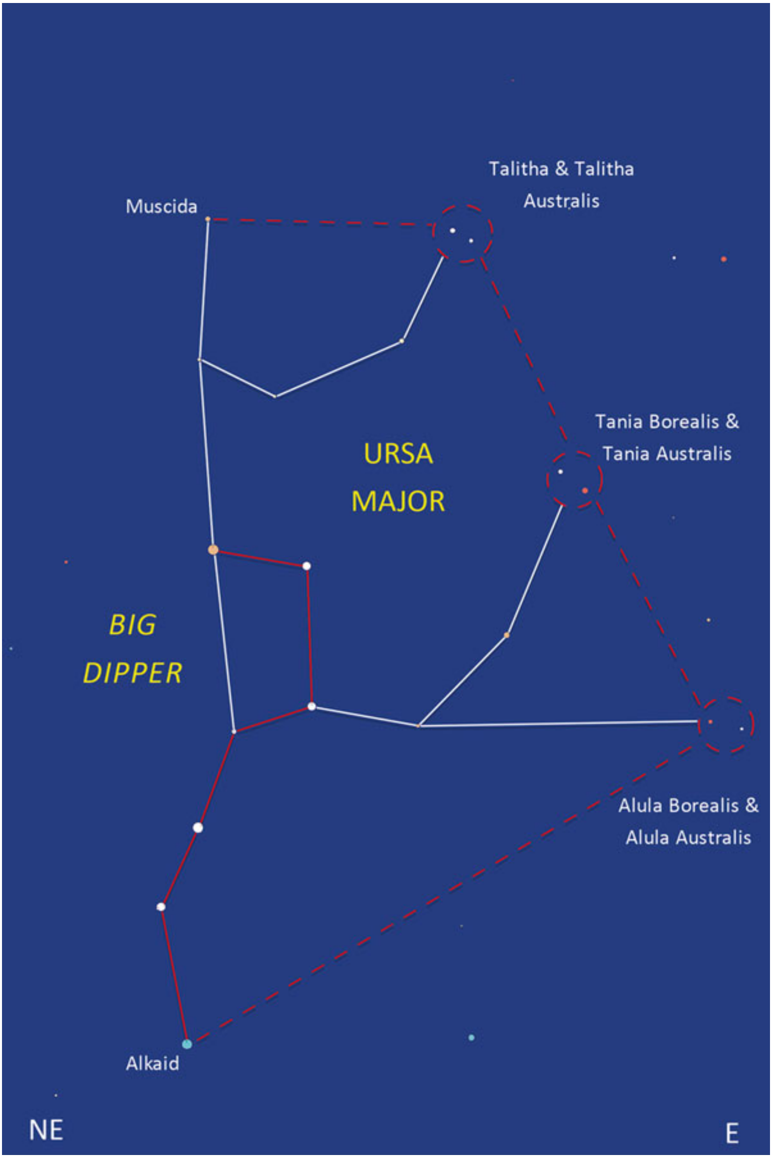

Fig. 3.6 The huge constellation of Ursa Major contains the Big Dipper

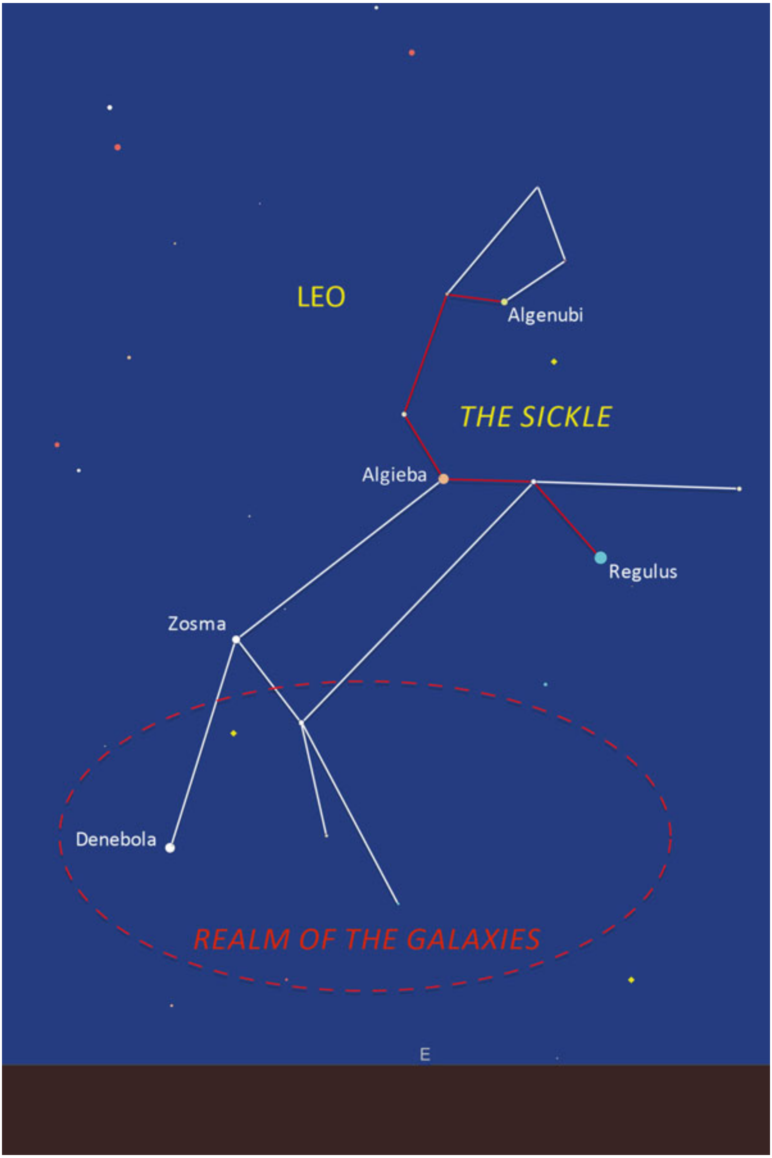

Fig. 3.7 The constellation of Leo hangs above the Realm of the Galaxies

Naked Eye Constellation: Leo

Thanks to it also being a sign of the zodiac (Chap. 6), Leo is a well known constellation. Though it's supposed to represent a lion—a shape that's easily possible to imagine just by looking at it—I always look for the backwards question mark (also known as the Sickle) that makes up the lion's head (Fig. 3.7). Bright star Regulus is the dot on that question mark, with Denebola the tip of the tail. These two most easily seen stars in Leo are 79 and 36 light years distant, respectively.

Under the Lion's Belly

It's not what the constellation itself is made-up of, but rather what can be seen deep within its boundaries in that region of sky; just below the lion are the Leo Triplet of galaxies—M65, M66, and NGC 3628—the latter a spiral galaxy similar to our own. All make great targets for a large telescope, but the naked eye or even binoculars can't detect them.

The Astronomical Calendar

Ready for some precision stargazing? Just as movie theaters have schedules and newspapers list local events, the night sky also has a timetable. The only difference is that most of what happens in the night sky can be calculated well in advance. Usually millennia.

Conjunctions, Elongations, Eclipses and Oppositions

You can stargaze any clear night, but timing is everything if you want to witness a fleeting celestial event. How about seeing a bright Jupiter or red giant Aldebaran close to the Moon? Or Venus and Mercury together just after sunset (Chap. 7)? When two celestial bodies are unusually close to each other in the night sky, it's called a conjunction, though to know about such things in advance means getting hold of an astronomical or stargazing calendar.

These will give you advance warning on when you can witness a planet at opposition, which is when Earth is between the Sun and a planet, so at its closest and brightest. Or a maximum elongation, when Venus or Mercury appear to be at their furthest distance from the Sun, and so more easily visible after sunset. Also when solar and lunar eclipses are going to occur.

Don't rely on the mainstream media to highlight interesting celestial phenomena. Journalists often get excited about comets, asteroids coming anywhere near Earth, and perhaps the odd meteor shower, but that's about it. You need to arm yourself with some reliable stargazing news sources.

Useful Websites

If you don't want to miss anything, then several websites are on hand; the astronomical calendar at www.in-the-sky.org is useful because it tailors a diary not only to your exact location, but also shows you only those events that you will be able to see. For instance, choose 'naked eye only' and it will give you the phases of the Moon, meteor showers and eclipses, but change that to 'visible thorough a four-inch telescope' and you'll also get details of various galaxies, star clusters and the more distant planets. The Sea & Sky[1] website is great for inspecting upcoming celestial events, too, though my personal favorite is the slick and simple EarthSky,[2] which emails a daily update that includes details of what to look for in the northern hemisphere night sky tonight, photos of yesterday's significant celestial event (perhaps a close conjunction of Venus and the New Moon) and other science news.

It's also worth putting search terms like 'top 10 astronomical events' into a search engine at the beginning of every year to find articles on the upcoming eclipses, meteor showers, conjunctions and perhaps even comet sightings that you absolutely need to know about in advance. Why do you need to know? Because no-one wants to be flying home from their annual holiday during a total solar eclipse, or—much more likely—accidentally planning a road-trip through, or a vacation in, dark rural skies during Full Moon week when the stars are all but obliterated. That would be a huge shame. In stargazing, planning is everything, so put anything that might be relevant to you in your diary or calendar.

1 www.seasky.org

2 www.earthsky.org

Coping with Disappointment

Just as important as knowing exactly what's going to be happening in the night sky later on that day is being relaxed enough not to get too annoyed when the inevitable clouds drift over to ruin the chance of observing something potentially very special. I recently traveled to the Faroe Islands in the North Atlantic to witness a total solar eclipse. All but a handful of the 8000+ eclipse-chasers (Chap. 14) who had traveled across the globe to be there saw nothing. That's just the way it goes with stargazing and astro-travel, so it's best to cultivate a relaxed attitude towards the weather and always have a Plan B.

How to Be an Outsider

Night vision takes time to cultivate and only second to destroy. There's nothing worse than heading outside in your winter coat and spending 20 minutes dark-adapting your eyes before realizing that you've left your torch/binoculars/sky chart/house keys inside. There are many other faux pas that practiced stargazers try to avoid. Here's a few things to remember:

Clear the Area

Take down the clothes-line in your backyard and put the lawnmower away—both are stargazing hazards. Ditto chairs and other garden furniture, though a table can be handy for storing equipment such as books, drinks and binoculars.

Switch-off the Lights

Light pollution in your own backyard is easily avoided, if it's coming from the back of your house. If you've got a motion-sensing light, deactivate it.

Full or Spare Batteries

Before you stargaze, test your red-light torch batteries or always take some spares outside with you. Make sure your smartphone is charged, dim the screen's brightness to minimum, and engage the red-light mode on any stargazing apps you might use. Also switch to airplane mode to stop incoming calls.

Stargazing Uniform

Stargazing can come with a lot of paraphernalia—especially in winter—and instead of assembling it all each night, it can be useful to have a coat, scarf and hat ready to put on quickly.

Pen and Paper

Always take something for noting down objects, questions or notes to research later. Some stargazers like to keep an observing diary, too, to keep track of what they've seen, when, and in what conditions. Waterproof notebooks can be useful for protecting against dew.

Phases of the Moon

The Moon is always half lit by the sun, but from the surface of the Earth, it doesn't look that way. This is just as well for stargazing; as the Moon orbits the Earth, the visible sunlight it reflects waxes and wanes. Slowly throughout the month the crescent Moon will wax towards a Full Moon as it gets further from the Sun, then wane back towards a crescent Moon as it gets closer. Moon-watchers have divided up the Moon's 29 day orbit into eight distinct phases (Fig. 3.8), each lasting for about 3.5 days, and each with a rather confusing name. Knowing where the Moon is in its cycle is all-important for stargazers.

Fig. 3.8 The phases of the Moon. Credit: NASA/Bill Dunford

New (Rises at Sunrise, Sets at Sunset)

When the Moon is between the Earth and the Sun, it's virtually invisible since the Sun is illuminating the half of the Moon that's facing away from Earth. It rises at sunrise and sets at sunset. Total solar eclipses (Chap. 14) can only occur at this time, but are rare since the Moon orbits Earth around 5° off the ecliptic.

Waxing Crescent

For the first few days after the New Moon, a slowly increasing crescent Moon can be seen in the western sky just after sunset and just before sunrise. Try to catch it a few hours after its New phase and you'll see the arresting sight of a very slight slither of a crescent Moon. Since it's still in the general direction of the Sun, it's during these first few days that you're most likely to see a

crescent Moon accompanied by Venus, and possibly Mercury, too (Chap. 11). This is also a great time to study features on the right-hand side of the Moon, as seen from the northern hemisphere (Chap. 11).

First Quarter (Rises at Noon, Sets at Midnight)

Since the Moon is always 50 % illuminated, the name for this phase is misleading; it describes what we can see from Earth rather than what's going on. I prefer to call this stage of the Moon's orbit Half Moon, because it occurs when the Moon is at a 90° angle to the Earth and half-way on its journey towards Full. Since the Moon is now rising around noon and setting around midnight, stargazing is still possible, though becoming more difficult.

Waxing Gibbous

If the word crescent to describe the Moon's illumination is descriptive, you're less likely to have come across gibbous. Also known as egg phase to stargazers, a Waxing Gibbous Moon describes the phase from half-lit to Full. The terminator, the line that separates the lit and un-lit parts of the Moon, begins to bulge-out to the east. Stargazing begins to become difficult as the Moon's increasing light washes-out the sky, and it sets in the small hours, well after midnight.

Full (Rises at Sunset, Sets at Sunrise)

Just like a New Moon, a Full Moon is when the Earth, Sun and Moon are aligned. This time, however, Earth is roughly between the Moon and Sun, so the Moon is fully illuminated by the Sun. At this time, the Moon rises at sunset and sets at sunrise. It's so bright, it can be blinding if you stare at it, and the light pollution it sends in all directions is all-encompassing. Watching a Full Moon rise is a beautiful sight (Chap. 8) for a few days, but this is not a good night—or even a good week—for stargazing. At Full Moon is the only time it's possible to witness a lunar eclipse (Chap. 14), when the Earth's shadow blocks sunlight from reaching the lunar surface, though the Moon's wobbly orbit makes this rare.

Waning Gibbous

With this phase, the night sky's chief light polluter drastically drops in brightness. It's another egg phase, which is something of a relief not only because the Moon is less illuminated, but because it rises later. During this phase the Moon rises about 9 p.m. and beyond. At this time of the Moon's orbit, it's still very bright and can interfere with stargazing, but conditions are about to drastically improve.

Third Quarter (Rises at Midnight, Sets at Noon)

This is exactly the same as a First Quarter Moon, and better called a Half-Moon. A Third Quarter Moon rises about midnight and sets at noon, so it's common to see this phase of the Moon during the day. It also signals the beginning of 2 weeks of Moon-less nights, so primetime for stargazing. If you're planning a trip to a dark sky destination (Chap. 15), the two weeks between Third Quarter and First Quarter Moon are ideal.

Waning Crescent

Another daytime Moon view is the Waning Crescent, which sees the illuminated Moon shrink to back to new. By this time the Moon is rising at 3 a.m. and setting before sunset, so it's not a Moon most stargazers often see. Is it worth getting up early to see a Moon that looks very similar to the much more conveniently-timed Waxing Crescent two weeks previously?

When to Moon-gaze

Definitely in the first week after a New Moon, which is its Waxing Crescent and First Quarter phases. As well as it not being as bright and dazzling as during the following Waxing Gibbous and Full phases, it's also visible at a sensible time of night if you stargaze before bed.

The rule of thumb is this; if it's a good night for stargazing, it might also be a good night for Moon-viewing. The exception is after the Full phase, when

Fig. 3.9 Earthshine is visible a day or so before and after New Moon. Credit: ESO/Y. Beletsky

the Moon rises later and later; the Moon's Third Quarter and Waning Crescent phases are not seen by many stargazers since they don't rise until the small hours. The Moon in these latter stages of its orbit becomes a pre-dawn object for early-risers only (Fig. 3.9).

Naked Eye Target: Earthshine on the Moon

The best time to see Earth shine is a few days either before or after New Moon. You'll need to go outside somewhere with a reasonably good view of the western sky to see it, but as well as looking beautiful in itself, a Crescent Moon is never dark. If you look carefully at the dark area of the Moon, you'll see some detail; that's sunlight being reflected by the Earth onto the Moon.

Earthshine is always there, but by First Quarter Moon it's impossible to see. It's really a trick of the eye; the contrast between the lit area and the dark

area is, for the only time all month, small enough for your eye to see both. As the Moon becomes more brightly lit, your eyes become overwhelmed by the glare and can no longer see Earthshine.

The Philosophy of Naked Eye Stargazing

Next month we'll consider how binoculars can help stargazers unlock the next layer of the night sky, but that doesn't mean leaving behind the wide-eyed view.

Using binoculars or a telescope causes many people to confuse stargazing with astronomy, but they can be distinct disciplines. "Looking at stars has an effect on everybody, it has a special way of getting into people's souls," night sky activist Chris Luginbuhl at Flagstaff Dark Skies Coalition, and a retired astronomer at the US Naval Observatory, told me during a stargazing trip to southwest USA. Despite his qualifications and his career, Chris is something of a guru when it comes to the wide-eyed view; he doesn't care to mix-up stargazing and astronomy. "Astronomy implies science, and stars are a bit more immediate, and accessible to anyone," he says. "You can be a kid or a sales clerk or a janitor who knows nothing of math, or you can be a PhD astronomer, and still feel the same level of connection to the night sky."

The wide-eyed view is also the only way to appreciate the depth of space, though there's no need for math or physics. "You don't need to know numbers, just know that it's deep and know that those stars, even though they don't look like the Sun, are basically the same as the Sun, just very far away," says Chris.

Use Your Eyes

Binoculars and telescopes are very useful for studying the sky, but they're completely optional; if over-used they can act as a barrier between the stargazer and the stars. "Just get out there and use your eyes—everyone has them, and you don't need technical equipment to see the Universe overhead," says Chris. "When you look directly without instrumentation there's an immediately of the connection between you and the stars."

It's tempting to use binoculars and a telescope, and there's no reason not to, but always be aware of the wide-eyed view. "People see photographs all the time of the beautiful things that are accessible by telescopes, and to some level instrumentation can help you see some of that," says Chris. "You can look at clusters and planets through telescopes, and that's moving to a lot of people, but the immediacy of just using your eyes is so valuable. The real connection is made when you get the whole panorama of the overhead sky with its thousands of stars. The light that you see is really from those stars, trillions of miles away, emitted hundreds, thousands or even millions of years ago—not from a computer screen or a page." Above all stargazing is about making a connection with the Universe as it really is.

Sideways into Space

You can stargaze however you prefer. Some stand, others use a deckchair, and a few like to lay on the ground. The latter isn't always practical, but it can help you 'get' the wide-eyed view (and it's great for meteor showers, too). "Lying down connects you better with the Earth," says Chris. "The first thing is that it's logistically the best way to stargaze because your eyes are pointed in the right direction and you're comfortable—you don't get a crick in your neck—but you can get more philosophical about it."

Lying on the floor is the most effective way of mentally disconnecting from any geometrical notions of up and down, away and near. "When you're lying on the ground, imagine that you're stuck to the Earth, and that you're facing sideways out into space," says Chris. "By imagining that you're facing sideways you'll get yourself into a different frame of mind. Imagine that you're looking out rather than up." Simply laying on the floor can give you a valuable new perspective.

"I encourage people to go outside in the warm season, find a nice place to lie on the ground and just watch the whole progression of the night—you can watch what I call night's window opening," says Chris. "During the daytime the drapes are drawn. As the night comes in and the air becomes dark and transparent it's like a window opening. Go through that process and watch it happen."

The Importance of Patience

Few people give more than five minutes to stargazing, and even people who are interested in making a connection with the night sky often don't understand that you can't do it in a minute or two. The eye adapts to the dark slowly. "Most people step outside and look up and they see a couple of stars and they go back inside," says Chris. "They haven't seen a tenth of what they would see if they were to stay there for 10 minutes, or a fiftieth of what they would see if they were to stay there for half an hour."

By now, you know this all too well yourself, having spent some time watching the star reveal themselves. You're part of a tiny minority of humans who've got the patience, but your timing is also excellent; what's above us in the night sky is being revealed by astronomers for the first time, and it's all happening in our lifetimes. But forget armchair astronomy; stargazing is a spectator sport. As the northern hemisphere begins to warm-up in spring, you've got a ring-side seat.

References

Dunlop, Storm. Night Sky: Get to Know the Natural World. HarperCollins, London. 2004.

Encyclopedia Britannica. Sextans & Benjamin Apthorp Gould. [ONLINE] Available at: http://www.britannica.com [Accessed 01 June 15]. 2015.

Odenwald, Sten F. The astronomy cafe: 365 questions and answers from ask the astronomer. Palgrave Macmillan, USA. 1998.

Sessions, Larry & Byrd, Deborah. Arcturus cuts through galaxy's disk. [ONLINE] Available at: http://earthsky.org [Accessed 01 June 15]. 2015.

Strobel, Nick/Astronomy Notes. Motion of Our Star the Sun. [ONLINE] Available at: http://www.astronomynotes.com [Accessed 01 June 15]. 2015.

PART II

A CLOSER LOOK

CHAPTER 4

APRIL: THE GALAXY REVEALED

The Stars of April

April is when many stargazers—especially those in the northeastern USA and Canada—have temperatures just warm enough to contemplate stargazing for more than a few minutes. If that's you, I hope you use those minutes wisely.

With Orion and the stars of winter now setting in early evening, it's time for a new adventure. Having learned some basic constellations and the positions of some bright (and not so bright) stars, it's time to cast our eyes even further into the cosmos. There are other layers to the night sky that only optics can help unlock, but a telescope can wait; at this stage of your stargazing, two eyes are better than one. It's time to invest in a pair of binoculars. They're not expensive, but they are expansive; use them wisely and widely and the night sky will seem a whole lot deeper—and you'll see some beautiful sights that would be impossible with a telescope. With some magnification, we can see the night sky's second layer, which is where it begins to look more like what it really is—the inner workings of a vast, astonishing galaxy. Forget the few hundred[1] stars you can see with the naked eye; you're about to gain access to hundreds of thousands.

Before we go deeper, take a step back and learn one of the night sky's most famous star-hops, see a sure sign of spring, and maybe glimpse a shooting star or two (Fig. 4.1).

[1] Technically it's possible to see 5000–10,000 stars with the naked eye, but only under perfect conditions. From most backyards it's nothing like those figures.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_4

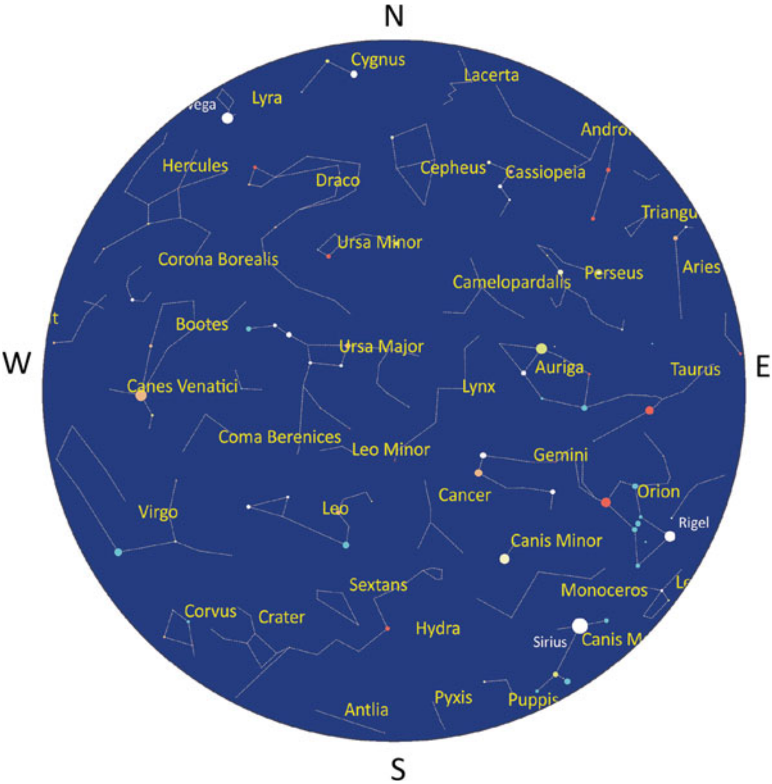

Fig. 4.1 Star-chart for April 1 at 10 p.m.

Star-hop to Spica

We've already seen the constellation of Bootes (Chap. 3), going Arc to Arcturus from the tail of the Big Dipper. However, the rest of that memory aid is revealed this month as the bright star Spica—essentially a summer star—appears above the horizon, replacing the sinking Sirius.

Arc to Arcturus , Spike to Spica

Here's a memorable way of quickly finding two of summer's dominant stars, orangey Arcturus in Bootes (Chap. 3) and blue-white Spica in Virgo. Simply locate the Big Dipper in the northern sky and follow the handle arcing away from the core of that constellation (Fig. 4.2). The next really bright star you get to is Arcturus. It's a slightly tricky maneuver because you're coming from one side of the sky to the other, crossing the zenith, but the next bit is easier on your neck. Once at Arcturus, travel about the same distance again as a 'spike' down towards the horizon, and slightly to the west, to another bright star. That's Spica.

Naked Eye Target: Spica

Spica is resolutely a summer star for those of us in the northern hemisphere, and it's at its best each June. Spica is short-lived in our skies, first visible in April and gone by September. It doesn't rise high above the southern horizon, but with some jostling you should be able to glimpse it between buildings or trees. Visually it's the 15th brightest star in the night sky, though it's actually a binary star system (a 'real' double star) about 242 light years from us. Next month we'll look at the constellation of Virgo, which Spica resides in (Chap. 5).

Naked Eye Asterism: The Spring Diamond

We've had the Winter Circle with the Milky Way running through it, so this month it's time for another giant asterism for spring that frames the remote galaxies of the Virgo Cluster (Chap. 5). The Spring Diamond (Fig. 4.2) resembles a kite rising on its side. It's made from four stars, with Arcturus in Bootes and Denebola in Leo (Chap. 3) marking the sides. At the bottom is Spica near the horizon while marking the top is Cor Caroli in the tiny two-star constellation of Canes Venatici. Go from Spica up towards the Big Dipper's tail, straight above your head. About two-thirds of the way there is Cor Caroli, which is relatively faint, but easy to find. We'll revisit Cor Caroli much later this year with a telescope; it's actually two brilliantly colorful stars (more on them in Chap. 10).

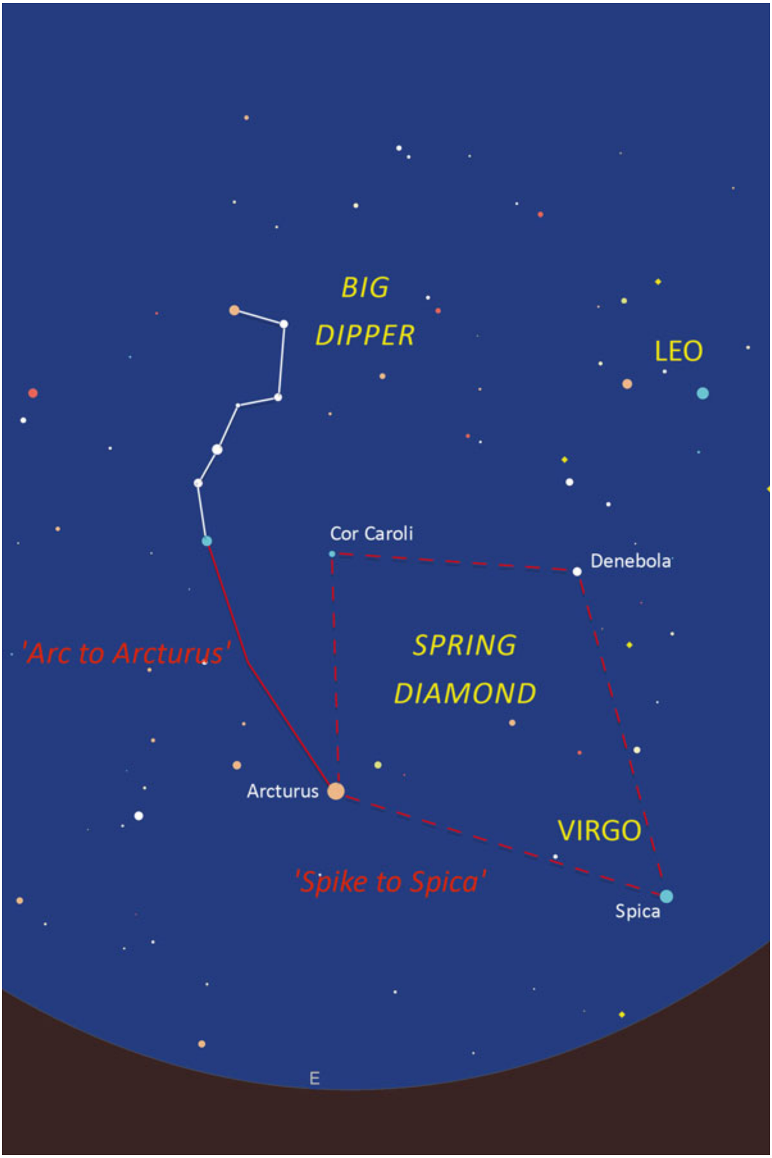

Fig. 4.2 'Arc to Arcturus & Spike to Spica' is a spring signpost, but also look out for the Spring Diamond asterism

The Lyrids

A *shooting star* is a meteor hitting the Earth's atmosphere and burning up, and you've probably already seen dozens of them. They happen regularly enough for a stargazer to see them frequently any time of year, but meteor showers are predictable. One such meteor shower is the Lyrids, which happens in mid-April as Earth's orbit takes it into the dust and debris left over from a comet's passing (Comet Thatcher, which last visited the solar system back in 1861 and won't return until 2276!). It gives stargazers a small chance of seeing some seriously good shooting stars. It's one of the oldest, so not the best meteor shower of the year, with about 20 meteors per hour normal. But what the Lyrids lack in quantity they can make up for in quality; watch out for bright fireball trails behind the occasional shooting star, which can last a few seconds. A stunning sight!

Naked Eye Target: Lyrids Meteor Shower

If you can stand being outdoors for a few hours, seeing a Lyrid fireball is a memorable experience. The display lasts about a week in the middle of the month, and peaks around April 22–23 (check an astronomical calendar for exact dates), so plan some stargazing during this week and you might get very lucky. The fireballs can appear anywhere in the sky, but they originate from the northeastern sky in the slowly rising constellation of Lyra (Chap. 5), hence the naming convention.

Should I Travel to Watch the Lyrids?

In short—no. The Lyrids are not intense enough to warrant much effort. There are much better, stronger meteor showers coming later in the year, such as the Perseids in August (Chap. 8), the Leonids in November (Chap. 11) and the Geminids in December (Chap. 12). A Last Quarter or Full Moon can easily wash out the Lyrids, so check the phase of the Moon and, if it's going to be bright, check precisely when it sets and stargaze after that, if possible. It's better to simply stargaze for an hour or so on the peak nights of the Lyrids rather than make a special occasion of it.

A New Layer

It's time for a closer look. A pair of binoculars will help us look deeper into the constellations and the night sky around them. Why not a telescope? Well, we'll get to a telescope eventually (Chap. 9), but binoculars have four huge advantages over a telescope at this stage (and, indeed, any stage) of your stargazing career. Firstly, they're portable, which means you can easily take them on vacation as well as just leaving them in your vehicle or your luggage. Secondly, binoculars will give you an upright, stereo view of the heavens, unlike the one-eyed view through a telescope. Thirdly, you'll get a far wider field of view than through a telescope, which is ideal for looking at objects of a certain size. For instance, the stars of the Pleiades look stunning in a pair of binoculars, but far less so in a telescope. Lastly, binoculars are much easier to aim and focus than a telescope. If you're more interested in stargazing than gadget-gazing, binoculars are what you need.

Binocular Target: The Night Sky

If you have any kind of binoculars in the house, or can borrow some from a friend, get outside an hour after sunset and point them at the Pleiades. Instead of the five or six stars you can see with the naked eye, hundreds become visible. Look anywhere else in the night sky and you'll also see hundreds of previously invisible stars, but from the Pleiades slowly turn to the north scanning across the sky as you do. You'll pass across the stunning star-studded sky around Perseus (Chap. 11) and Cassiopeia. This exquisite view of the night sky is only open to those using binoculars.

Access All Areas

Hopefully you're already hooked, having seen with your own eyes how binoculars allow you to access a whole new layer to the night sky. That doesn't mean you've moved beyond the wide-eyed view, which links the night sky to the landscape you're in. But binoculars unlock a whole new category of truly beautiful celestial sights. This month we'll begin to glimpse some of those sights, but first let's begin with some buying advice.

Choosing Binoculars

Stay handheld and highly portable. At this stage you don't need to buy a special pair of binoculars designated only for astronomy. There are various antireflection lens coatings that can increase the brightness and improve the sharpness of the images, but neither are particularly important at this stage.

You may already own a pair of binoculars that will do just fine, though it's likely you'll want to upsize slightly. Before we consider sizes, you should know that buying binoculars is all about marrying up magnification and brightness. The first number in the specification for a pair of binoculars denotes the magnification (or power), while the second number describes the aperture. So, a pair of 7×50 binoculars offers you an image that is seven times bigger than what you would see with your naked eye. The second number, 50, is the diameter in millimeters of the objective lens, which is the optics on the front of your binoculars. This is simply about how much light is gathered, and so how bright the image can be.

Any pair of binoculars with over 10× magnification is almost impossible to hold steady enough without a tripod to make out detail. It's best to go into the store and try out some binoculars yourself, but as a rule of thumb a pair of binoculars with the ratings of 7×50, 10×42 or 10×50 will do just fine, and shouldn't cost you more than about $100–$150. However, there are a few other things to think about: since you'll be outdoors, a waterproof design makes a lot of sense. The more compact and lightweight they are, the better if you plan to travel with them because they will need to go in your carry-on baggage. Lastly, try to find a pair with twist-up eyecups, which are easier to look through and help block ambient light.

The Magnification Myth

It might appear counter-intuitive, but magnification isn't everything; the field of view you'll get with 7×50, 10×42 or 10×50 binoculars is perfect for many night sky sights. If you opt for more power—e.g., a pair of 18×50, 15×70 or 20×50 binoculars—you'll not only get a narrower field of view, but the image shake dramatically increases. Trying to find tiny sky objects becomes very difficult at higher magnifications. Tempting though they might be, avoid buying binoculars with higher magnifications just yet.

Advice on when and why to buy bigger binoculars, how to use them, and why they can be worth the hassle will come later (Chap. 12). For now, 7 × 50, 10 × 42 or 10 × 50 are more than enough; I guarantee you'll use them more than any telescope you buy at this stage.

First Light

Stargazing and astronomy on every level is about light, so when a brand new telescope gets used for the first time, it's called *first light*. To get you started with your new optics, here are five sparkling sights that look best in binoculars.

Binocular Target: Mizar and Alcor

You've seen these two before (in Chap. 1), but could you split them with just your eyes? If not, you should now have no trouble seeing both Mizar and Alcor in the Big Dipper as individual bright stars through binoculars.

Binocular Target: The Moon

Forget the Full Moon and instead point your binoculars at a crescent or First Quarter Moon this month; in addition to seeing shadows thrown by the Moon's many craters, you might even see *Earth shine*, twice reflected light from the Sun that first hits the Earth, and then the Moon (Chap. 3). You'll also begin to get an understanding of both the magnification and the field of view of your binoculars.

How to Focus and Calibrate Binoculars

It's essential to know how to operate your binoculars. If you don't know exactly what you're doing, you'll not only get frustrated with a poor image, but you'll also likely get a neck-ache, and quickly head indoors.

All binoculars have a focusing wheel on the top. Once you've chosen your target, look through the eyepiece with your right eye closed, then rotate

the focus ring back and forth until you get a sharp image in your left eye. Now close your left eye and open your right eye, and adjust the diopter ring (which is usually found on the right eyepiece) until your right eye sees a clear image. It's this second step with the diopter ring that most people ignore, but it can make a big difference, because the binoculars are now calibrated to your specific vision.

How much of the night sky you'll see in your binoculars—the *field of view*—depends on the specifications; 7× or 10× binoculars will show you, on average, around eight degrees of sky.

Binocular Target: The Pleiades

Setting in the west, this star cluster 440 light years distant truly sparkles in a pair of binoculars. You might see five or six stars with your eyes, but hundreds in binoculars (Fig. 4.3). If we were on a planet around one of the stars

Fig. 4.3 The Pleiades through binoculars displays hundreds of stars. Credit: NASA, ESA, AURA/Caltech, Palomar Observatory

at the center of the Pleiades, we would see nine bright stars in the sky at least as bright as Venus is in our night sky (Consolmagno and Davis 2011). Be sure to observe the Pleiades this month as it will soon be gone until November.

How to Hold Binoculars

Stargazing is all about standing out in a backyard or some other outdoor location for long periods of time, and often in the cold. Light pollution can be a problem, but one easily combated by holding your binoculars correctly. There should be a neck strap eyelet on each side of the body of the binoculars, and a neck strap in the box. When fixing these, make sure they hold very tight since it's all too easy for binoculars to fall to the ground and become permanently damaged. It's best to keep the neck strap fairly short so the binoculars sit on the upper part of your chest. This way, they won't make your neck ache. You should always hold your binoculars with two hands firmly on each side.

If you have bright lights within your field of vision, such as a street light, bring your hands back towards your eyes, thereby blocking out any glare with the sides of your hands. This can be a little awkward since you're also loosening your grip on the binoculars, but it's a technique that's worth perfecting since you can get a much more immersive image.

Binocular Target: The Orion Nebula, M42

Also dropping out of view soon is Orion's Sword (Chap. 2) below the three Belt stars, which is home to the Orion Nebula around 1270 light years from us. It's going to be hidden in the haze of the horizon this month so far from its best, but it's worth a last-gasp look. Can you make out the newborn Trapezium stars right in the centre of this glowing misty patch (Fig. 4.4)? If not, have a closer look in December (Chap. 12) when it's back in the night sky.

Fig. 4.4 The Orion Nebula (M42), is in the middle or Orion's Sword, with the three Belt stars to the upper-right. Credit: ESO/S. Brunier

Reducing Image-Shake

Image-shake is a big problem that is easy to reduce. If the image in the binoculars is trembling and blurred (it probably will be), prop-up your elbows on your chest to keep your arms steady. However, this only works well if you're aiming the binoculars fairly close to the horizon. Cures for image-shake are myriad; leaning against a wall, place your binoculars on top of a fence or railing, or use an upturned broom to support them. Image shake gets worse as your arms get tired, but you can easily lessen that if you lay down on the ground or sit on a chair. Similarly, if you get into the habit of sitting while you use binoculars (though you will have to lean back a lot) you can eliminate 80 % of the neck ache that most binocular-wielding stargazers experience.

However, the most important thing to remember is to decide what you want to look at before you point your binoculars at the night sky. There's a lot of stars out there, and just idly sweeping your binoculars across the sky is likely to leave you lost, frustrated, and with tired arms and a shaky image.

Binocular Target: The Perseus Double Cluster

Here's another object setting in the west that you should glimpse before it disappears until August. Visualize a line from Navi, the middle star in Cassiopeia (Chap. 1), to Ruchbah (the star directly to Navi's left if you think of Cassiopeia as a W-shape), then carry on the same distance twice more (Fig. 4.5). These two separate open clusters each contain hundreds of stars. We'll properly examine the glorious parent constellation, Perseus, later in the year (Chap. 11).

How to Wear Binoculars

Take time adjusting the neck strap so that your binoculars sit comfortably on your chest when you're not using them. You'll likely be pausing to look at a star-chart or smartphone app (in night vision-saving red mode, of course) frequently, so it's a good idea to make sure they won't get in your way between observations.

When wearing binoculars, keeping warmer becomes slightly more difficult. By wearing a neck warmer, or a hoody, you can keep the neck strap of your binoculars off the bare skin of your neck. Straining to look at objects overhead at the zenith is a stretch, which can instantly reveal your midriff to the elements; wearing a long (perhaps thermal) t-shirt that tucks into your pants is a good idea. Spare coat pockets, especially at chest height, are also handy for storing the lens caps from binoculars.

Binocular Target: M41 Beneath Sirius

Since Sirius (Chap. 1) is sinking, only those at latitudes of 30° south or less will be able to see the sparkling collection of open clusters that reside around one of our closest stars. If you can't see Sirius this month, bookmark this page for January or February next year—it's worth the wait.

Although a winter object, since it's just beneath Sirius in Canis Major, this open cluster is simple to find if latitude allows. If you can see Sirius from where you are, fix your binoculars on Sirius, putting it at the top of the field of view, then look at the bottom of the field of view (Fig. 4.6). You will see a Moon-sized cluster of 100

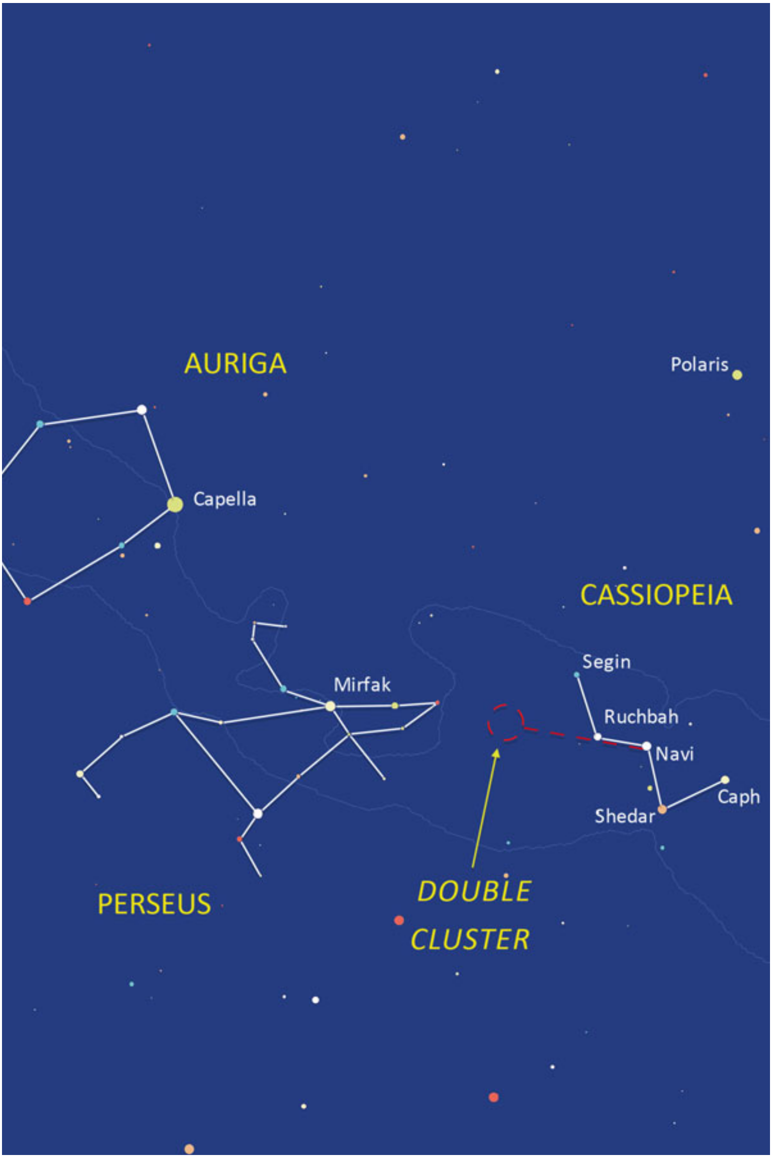

Fig. 4.5 Perseus and the Double Cluster, two separate open clusters each containing hundreds of stars

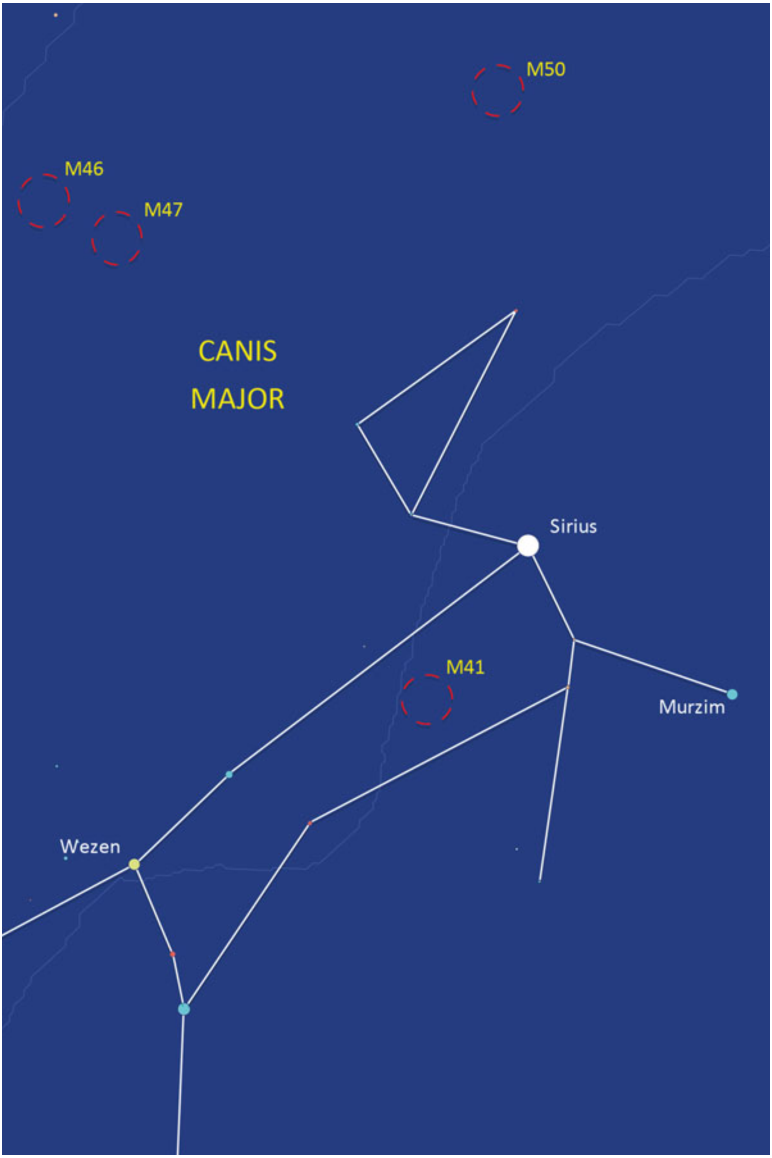

Fig. 4.6 Sirius, Canis Major and four open clusters nearby, including M41 just below

stars, which are around 2300 light years distant. This open cluster is most easily found in dark skies, which is so often the case with anything less than 10° above the horizon, though M41 is bright in binoculars. There are numerous other open clusters nearby, including M46, M47 and M50.

Avert Your Eyes

If some things in the sky don't appear as bright as you had hopped, it's because of the way your eyes are designed. The biology is academic, but just know that while your central vision is all about color, it's your peripheral vision that is most sensitive to brightness. Stargazers use a special technique called averted gaze or averted vision to maximize the brightness they see, and it couldn't be easier to do. Point your binoculars at the Orion Nebula and stare into its abyss. Beautiful, but not that bright. Leave your binoculars exactly where they are, but now look slightly above its center (go left or right and you might encounter the 'blind spot' that each of your eyes have). The massive, glowing cloud of gas and dust should light-up in front—or, rather, to the side—of your very eyes. Averted gaze is always worth trying, especially with star clusters and globular clusters (Chap. 5). Try it with the Pleiades, too; by looking just outside the cluster you should begin to see some of the bright nebulosity between the individual stars.

The Deep Sky

This phrase is often used to refer to objects that need some magnification. It usually relates to telescope targets, though you've already looked at some deep sky objects; the Orion Nebula, the Pleiades and the Perseus Double Cluster. Because of their large apparent size, the Pleiades and the Double Cluster are very much binocular targets. Anything that fills your binoculars' field of view—the Pleiades being the perfect example—is very much a binocular object.

The Orion Nebula, however, is slightly different. It tends to look better and better the more magnification you point at it, with a large 16-inch telescope (Chap. 12) able to bring out detail in the gaseous cloud around the Trapezium.

Two Red Giants

Orbit allowing, here's your first planet in close-up. Consult a stargazing app or an astronomical calendar to see if Jupiter is currently up in the night sky. If it is, locating it with the naked eye shouldn't be difficult since it's both very bright, and only ever on the ecliptic (Chap. 3).

Binocular Target: Jupiter and the Galilean Moons

Although Jupiter looks stunning in a pair of binoculars, it's not because of the planet itself. Find it in the sky this month and you'll be impressed by its brightness, though it's impossible to see its atmospheric bands or any surface color unless you have a telescope. Look closely and you'll see four tiny dots around the planet that move quickly; have another look an hour or two later and you'll see what I mean. Ganymede, Europa, Callisto and Io are known as the Galilean satellites, moons that were first spotted by the astronomer Galileo Galilei from Italy in 1610. Europa, the second one out from Jupiter, is a bit smaller than Earth's Moon. In December 2013, the Hubble space telescope detected water vapor above its south pole. It's thought that there's a liquid water ocean on Europa under an icy crust that could be as much as 100 km thick. We will revisit Jupiter later in the year with a telescope (Chap. 11).

Binocular Target: Betelgeuse

Look at this red supergiant with the naked eye and it has a definite orange tinge to it, but only if you look closely (Chap. 2). However, put some binoculars on it and it's unmistakably orange. This is going to sound counter-intuitive, but if you defocus your binoculars so that Betelgeuse expands, it looks even redder (Seronik 2007).

Sister Clusters

Open clusters are great targets for binoculars, and there are plenty to look at in April. Some fill the field of view in binoculars, while others are small, misty patches that can only be glimpsed. Star clusters contain stars of a common origin, but there's more to that story. Though they may be visible on different sides of the sky, seemingly separate star clusters can themselves share a common origin.

Binocular Target: Hyades Open Cluster

The Pleiades may get the most attention, but the constellation it is within, Taurus, has plenty of other jewels. The chief rival to the Pleiades is the Hyades, another binoculars-are-best cluster that we looked at with the naked eye earlier in the year (Chap. 2). An aging open cluster of over 600 million years whose stars have spread, it's best thought of as a blueprint for what the much younger Pleiades will become. The stars in the Hyades are just 150 light years distant, though as you scan around its dozens of spaced-out stars, note that the supergiant Aldebaran is merely a line-of-sight interloper (Chap. 2) that's much closer to the solar system at just 65 light years.

Naked Eye Constellation: Cancer

Look towards the east and south in April and you'll see an area of the night sky that looks emptier than in March when the Winter Circle stars were still dominating. However, since you know the locations of Gemini and Leo (Chap. 3), you may be able to identify the upside-down Y-shape of another zodiacal constellation (Chap. 6), Cancer, between the two (Fig. 4.7). Since it's a rather faint constellation it can be a difficult sight to find in urban skies, though there's little else around it to distract you.

It's worth an attempt, even if you have to use a smartphone app to tell you where it should be. Scan the area with binoculars and you'll soon notice dozens of close stars that betray the presence of one of the finest open clusters around. This is the Beehive Cluster.

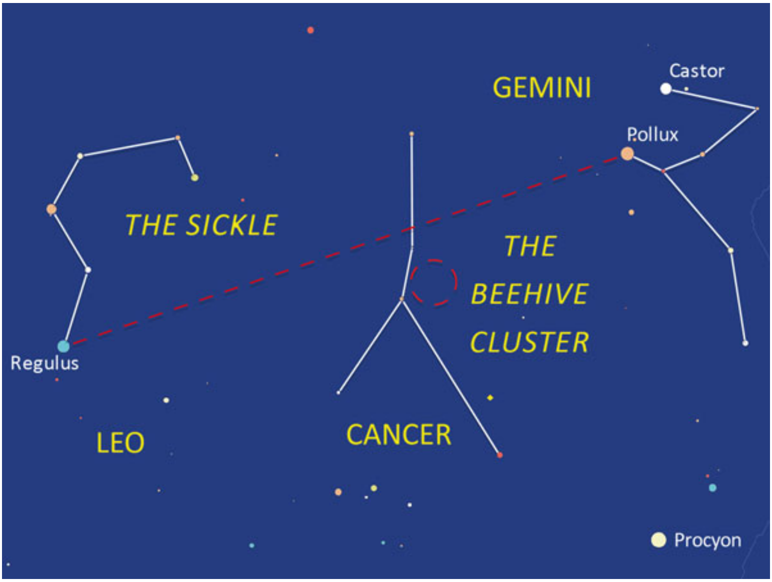

Fig. 4.7 The Beehive Cluster in Cancer can be found roughly halfway between Pollux in Gemini and Regulus in Leo

Binocular Target: The Beehive Cluster, M44

The Beehive Cluster is another good example of why a stargazer needs binoculars; it's just out of reach of the naked eye, but bright and obvious in binoculars.

About 580 light years distant in the constellation of Cancer, this open cluster is also known both as Praesepe and M44. It's just below halfway along a line imagined between bright star Regulus in Leo to Pollux, the lower star in Gemini (Fig. 4.7). It's generally immune to all but the worst light pollution. It's on the ecliptic, so the outer planets pass nearby. Over 100 light years further into the Milky Way than the Pleiades, the Beehive Cluster should look like about 60 stars in a pair of binoculars, though a dozen or so are particularly bright. It will be hanging around in the early evening sky until the end of May.

A Common Origin

Though they're significantly separated in the night sky both in position and light years, the Hyades and the Beehive Cluster probably have a deep connection. Despite the stars of the Beehive being much further from us than those of the Hyades, both clusters are of a similar age and size. What's more, astronomers have studied their motion across the Milky Way and measured them to be very similar (Rees 2011). Rewind their motion, and both the Hyades and the Beehive appear to come from the same stellar nursery in the Milky Way, somewhere much like the Orion Nebula (See Chap. 2).

Written in the Stars

The night sky defies any efforts to catalogue it in any meaningful way. However, that hasn't stopped people trying. The stars have had endless stories attached to them, with constellations created, studied and written about by myriad cultures. Stars have been catalogued by astronomers multiple times, some creating their own naming conventions and others happy to use existing norms. The end result is a bit of a mess and impenetrable to the casual stargazer, but there are some general rules that make it easier to wade through the Greek, Latin and Arabic, and the seemingly random naming conventions that attempt to put the night sky into some kind of order.

How Stars Are Named

Although many famous stars do have actual names, usually because of their brightness and prominence (such as Betelgeuse, Sirius and Procyon, for example), most do not. Officially all stars in constellations are ranked in order of their brightness, which makes the process logical, if not exactly easy. Rather frustratingly for beginners and anyone not armed with a classical education, Greek letters of the alphabet—alpha (α), beta (β), gamma (γ), delta (δ), epsilon (ε), zeta (ζ), eta (η), theta (θ), iota (ι), kappa (κ) (and so on)—are assigned to each star in a constellation, for which the Latin possessive is used, too! So, in the constellation of Ursa Major, the brightest star Dubhe is categorized as Alpha Ursae Majoris or α Ursae Majoris. The second brightest star, Merak, is called Beta Ursae Majoris or β Ursae Majoris, and so on.

Would 1 Orion, 2 Orion, 3 Orion etc. be easier to understand than having to learn both the Greek alphabet and the short-hand symbols for its letters? Absolutely. Blame Johannes Bayer, who came up with the system in 1600. As well as being rather irritating to learn, it's also not as logical a system as it could be. Rigel, the brightest star in Orion, is known as Beta Orionis or β Orionis, despite being brighter than Betelgeuse, which is known as Alpha Orionis or α Orionis. Go and have a look for yourself … it's a close match-up, but Rigel just wins. This could be because Betelgeuse is a variable star (its brightness changes over time) and has been known to at least approach Rigel in brilliance (Sessions 2015).

For general stargazing you can just about get away with not knowing any of this, but if you get handy with a telescope and go searching for galaxies and deep sky objects, it's helpful to know the Bayer system so you can read star-charts and star atlases.

There are numerous other naming conventions. The Flamsteed system is just as esoteric, naming stars according to their closeness to the western edge of a constellation. Under this geographical, more numerous but still rather confusing system used in John Flamsteed's Atlas Coelestis (1729), Dubhe thus becomes 50 Ursae Majoris while Merak is 48 Ursae Majoris.

As you'll see on deep sky star-charts, in a star atlas, in astronomy magazines or online, in practice what tends to happen is that for the really bright stars we use names, for the secondary stars in a constellation we use the Bayer system (alpha, beta gamma, etc.), and for the really faint stars we use Flamsteed numbers. You couldn't make it up!

How Galaxies Are Named

Where is the Andromeda galaxy (Chap. 10)? What about the Virgo Supercluster (Chap. 5) of galaxies? Answer: in the constellations of Andromeda and Virgo, respectively. The clue is in their names. It's easy to remember, but it does somewhat dampen the reality of what you're looking at. Galaxies are millions of light years away and have nothing to do with the constellations. Don't they lose their power and true, stunning nature when they're lumped into a list of

other stars and objects just because they're in the same general direction from Earth? Imagine if you could see, through your upstairs bathroom window, a huge city in the far distance that you'd never been to, and which was slightly illuminated at night. Now imagine calling it Alpha Bathroom Window. A crazy idea? Perhaps, but that's the system we use.

Stargaze enough and read around the subject and you'll get past the baffling naming conventions and get a proper appreciation of what you're actually looking at.

The Messier Mess

Stargazers and astronomers after deep sky sights are still using a catalogue—specifically the Catalogue of Nebulae and Star Clusters—published back in 1771 by French astronomer Charles Messier. He compiled his list of over 45 astronomical objects (now there's 110), but it's neither exhaustive nor accurate. In fact, all 110 objects can only be seen from the northern hemisphere. We've already covered a few of them—the Pleiades is known as M45, the Orion Nebula as M42 and the Beehive Cluster as M44—though the list also contains a confusing selection of supernova remnants (Chap. 2), globular clusters (Chap. 6) and galaxies. Anything that looked like a fuzzy blob went in; Messier wanted only to identify the permanent objects so he could systematically discount them during his obsessive search for comets.

For the casual stargazer, Messier's list is a mess, but it does contain some of the night sky's most fascinating sights. Most of the objects he identified can be seen in binoculars or in a relatively small backyard telescope. As a rule of thumb it doesn't make a good observing list, though March is the one time of year when it's possible to go on a Messier Marathon since the majority of the objects are somewhere in the sky during the night. A Messier Marathon is a common theme for star parties in March, but I would strongly advise you don't attempt it until at least your second or third year of stargazing. It's not only very difficult, but it's also not especially rewarding without a lot of knowledge about what you're looking it. It's far better to spend some quality time with each Messier object in turn, which we've already begun doing.

NGC, IC and HD Explained

They mean nothing, and everything. These updates to the Messier catalogue bring an unwelcome layer of more letters and numbers. Both were published in the latter nineteenth century when telescopes had dramatically improved from Messier's time; within the New General Catalogue (NGC) are a whopping 7840 additions to the Messier catalogue, with the Index Catalogue (IC) adding a staggering 5286 more. You'll come across objects marked NGC and IC when you start to use a telescope, as well as HD, which means Henry-Draper system. The most important thing to remember is that these letters don't accurately describe what kind of object it is; a galaxy can be known as M, NGC or IC, and often all of them. If there's an M and a NGC next to each other, don't make the mistake of concentrating only on the M object.

Need to Know

Stargazing isn't all about these conventions and numbers. In fact, it's better to ignore them since they can be misleading. What these naming conventions all have in common is that they're designed by, and for, succeeding generations of astronomers using different optics over hundreds of years.

Should there be a much simpler, but more comprehensive system solely for stargazers? I don't think so. Some sights are better with the naked eye, others in binoculars and many more are only visible through telescopes. There are also vast differences in both the equipment being used now as well as ever-rising levels of light pollution. It's therefore likely that any attempt to re-catalogue the night sky would just add more bureaucracy.

Diamonds, Dragons and Dippers

By now you should be looking for the north star each time you venture out after dark, darting from the Big Dipper straight to Polaris without thinking. It's the easiest star-hop of all, and the most important. However, Polaris

isn't on its own; as well as being part of a constellation in its own right, this month it is encircled from below by one of the largest constellations of all, Draco (pronounced dray-ko) the Dragon.

Naked Eye and Binocular Constellation: Ursa Minor

You may need dark skies for this, the little brother—and a flipped image—of Ursa Major (Chap. 3), but it's not difficult to find. You already know how to locate Polaris, which is the final tail star in the small constellation of Ursa Minor, which means the Little Bear. It's also known as the Little Dipper. Take the pointer stars from the Big Dipper, Dubhe and Merak, straight to Polaris and then take a curve back towards the Big Dipper (Fig. 4.8). The most prominent stars in this small, and often ignored constellation are bright stars Kochab and the lesser Pherkad, known as the Guardians, which lie in the same relative positions as Dubhe and Merak in the Big Dipper. Kochab and Pherkad are easy to spot with the naked eye to the right-hand side of Polaris this month at 10 p.m., though finding the other stars in Ursa Minor can be a challenge without binoculars.

Binocular Target: The Engagement Ring

Despite being only the 48th brightest star in the night sky, the fact that Polaris constantly sits over the north pole makes it a real jewel of the night sky. It also looks like one if you point binoculars at a pretty asterism including the star itself; six dimmer stars form a squashed ring shape (Seronik 2007). The bright Polaris acts as the diamond in the ring (Fig. 4.8).

Naked Eye Constellation: Draco

This giant dragon is one of the most difficult constellations of all to locate for most of the year, but it's temporarily well positioned during April. Look for the Big Dipper high above you and come down to an unmissable bright

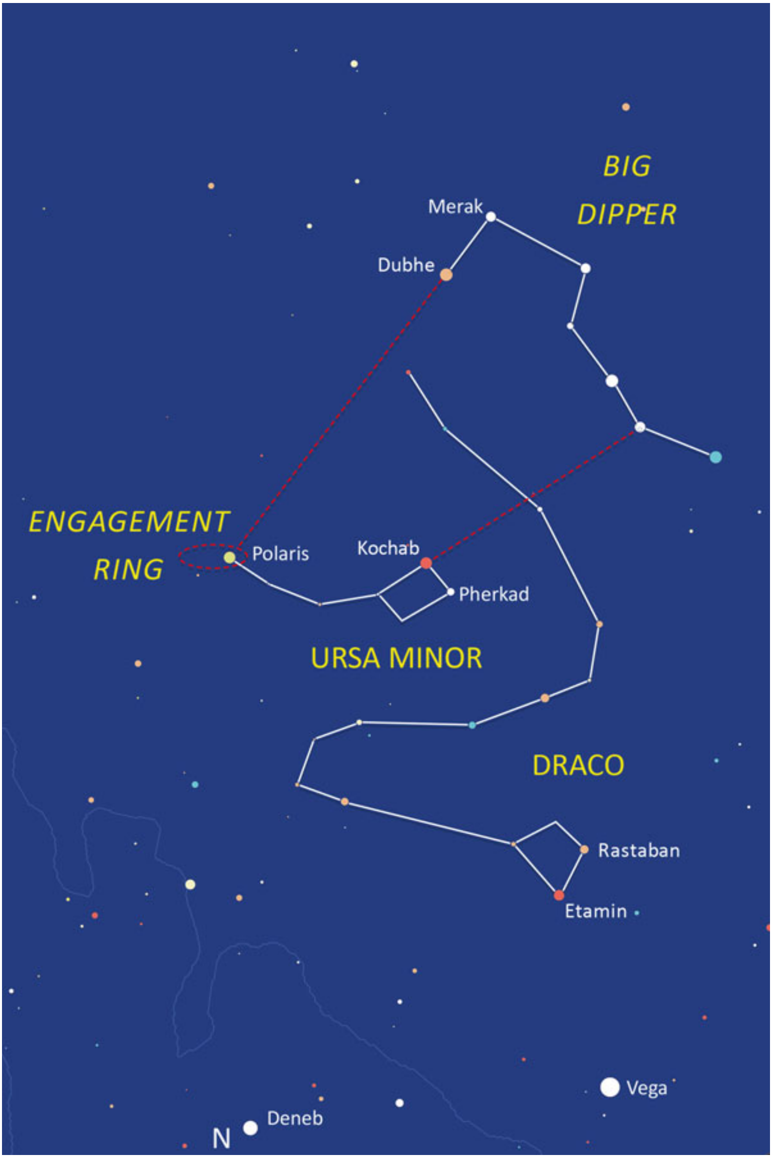

Fig. 4.8 Ursa Minor, the Guardians, the Engagement Ring and the huge constellation of Draco, which is easiest to find during April

star above the north-eastern horizon. That's Vega (Chap. 5). Draco curves in a backwards S-shape between the two. Draco's head is just above Vega; bright stars Etamin and Rastaban are joined by two others. Move west until you're under Polaris, go half-way back to Bootes, then curl around Ursa Minor, adjacent to the Big Dipper (Fig. 4.8).

Do We Need Constellations?

It's easy to get caught-up in the constellations, but the shapes they make are largely make-believe memory aids. Astronomy tells us that few stars in the major constellations are close companions. The patterns they appear to make are a product of little more than line-of-sight (such as Orion's Belt, Chap. 1) that can only be visualized from our viewpoint in the Milky Way. If that's the case, do constellations still matter?

Why Constellations Are Irrelevant

Now you've learned a few constellations, here comes the harsh truth: constellations are irrelevant. They may be a straightforward way of learning your way around the night sky, but they have two limitations. As well as many of the shapes being mere illusions, with the composite stars often not having much to do with each other, the stories attached to them are largely meaningless.

A lot of stargazing manuals include these myths, legends and stories connected with these imaginary shapes in the sky. Many books about stargazing never mention the scientific facts at all. Some claim that knowing the history behind these patterns enables you to read the sky.

However, unless you're a native of Ancient Greece, getting to grips with all of those myths and legends is a huge learning curve and all rather baffling, and by the end you'll have a closer understanding only of Ancient Greece. Constellations act as a wonderful cheat sheet for students of Greek legends, but to a stargazer who wants to know the true nature of reality and of Earth's place in the vast cosmos, they're distracting and irrelevant. The

real story of the stars is universal in the literal sense; it's about the miraculous scale and power of nature, a true story that we're only just begining to unravel. Who cares about Greek mythology?

So we should forget all about the constellations, right?

Why Constellations Are Essential

Never underestimate the power of storytelling. Constellations give the night sky a host of characters that are much easier to remember than single points of light in such vastness. Using well-known constellations is a useful, practical way of finding objects in a specific area of the sky. Take the Orion Nebula (Chap. 2); even if you're not sure exactly where it is, you will automatically turn to face the constellation of Orion and begin the search. This is why there are 88 official constellations in the night sky, each with a defined boundary; every star and every object has a basic zip code that anyone can read, and everyone uses. Astronomers name distant galaxies, nebulas and stars after the patch of sky they're found in, which will make no sense to future generations that may travel into interstellar space. But for now, our Earth-centric attitude to watching the cosmos and our quaint naming conventions will do just fine. After all, Greek myths have hardly hampered the miraculous march of astronomy in the last 100 years.

Myths and Method

There are many myths and legends linked to constellations that are useful to understand; Greek mythology has Scorpius (Chap. 7) and Orion as mortal enemies so puts them on opposite sides of the sky, with one rising as the other sets. That's based on celestial mechanics, and useful to know (though only those with a very low southern horizon will see Scorpius during the summer months). Meanwhile, the Navajo people of the Grand Canyon area of Arizona, USA (Chap. 15) call the Big Dipper and Cassiopeia constellations Revolving Male and Revolving Female, respectively, which is as instructive about the circumpolar nature of the northern sky as any stargazing book could be. Such stories that relate to the exact positioning and motion of stars in the night sky can be just as useful as science.

References

Consolmagno, Guy & Davis, Dan M. Turn Left at Orion: 4th Edition. Cambridge University Press, Cambridge. 2011.

Rees, Martin J (Ed). DK Illustrated Encyclopedia of the Universe Dorling Kindersley, London. 2011

Seronik, Gary. Binocular Highlights: 99 Celestial Sights for Binocular Users – Sky & Telescope Stargazing. Sky Publishing, USA. 2007.

Sessions, Larry/EarthSky. Rigel in Orion is blue-white. [ONLINE] Available at: http://earthsky.org [Accessed 01 June 15]. 2015.

CHAPTER 5

MAY: BINOCULAR TOURS

The Stars of May

The arrival of May sees sunset creep ever later, making stargazing almost a nocturnal activity. Though the hours of darkness are limited, sweeping binoculars over the night sky for longer becomes bearable as temperatures rise.

With the Big Dipper above our heads as this month's guide, night sky navigation can mean neck-ache, but it's harder to get lost. An easy way to lose your bearings is to look for stars your eyes cannot see, so this month we'll learn about magnitude and how to judge whether to use your eyes or binoculars (or both!) (Fig. 5.1).

The Universe at large continues to come into view in May. Distant double stars, globular clusters and galaxies in the constellations of Hercules and Coma Berenices are well positioned for binoculars. While they go back to the dawn of the Universe, there's time this month for some twenty-first century stargazing as the International Space Station streaks across the sky after sun-down. Can there be any grander a sight for stargazers than six humans in orbit?

Eta Aquarids

Early-rising stargazers get a treat this month. Peaking in early May—though ongoing from late April until the middle of May—the Eta Aquarid meteor shower can spray about 10–20 shooting stars every hour into Earth's atmosphere. Appearing to originate from the zodiacal constellation of Aquarius (Chap. 6), they're strongest in Moon-less skies in the early hours of the morning. This debris is leftover from Halley's Comet, which

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_5

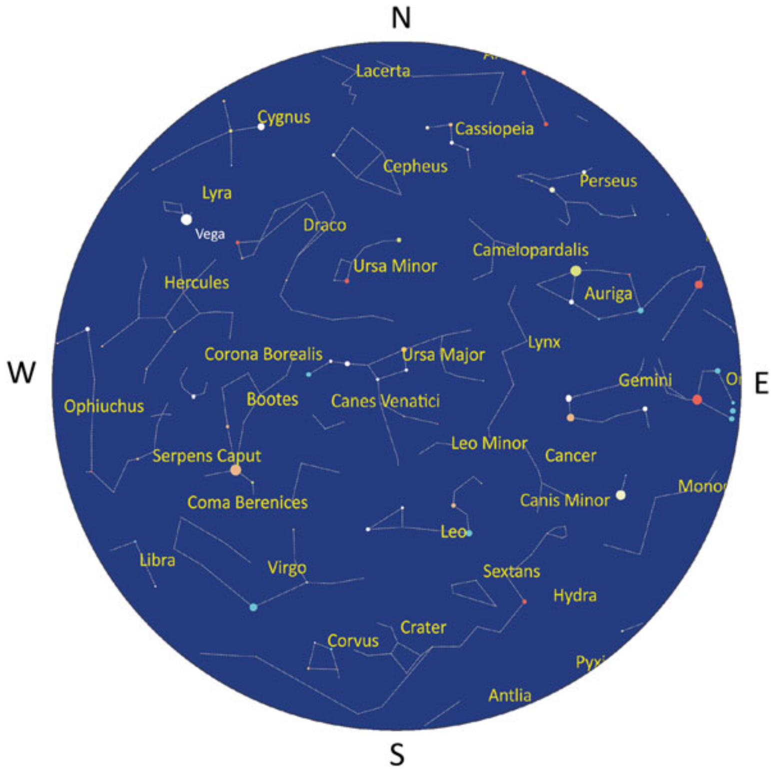

Fig. 5.1 Star-chart for May 1 at 10 p.m.

famously visited the solar system in 1986. On its way in and out of the solar system, it didn't just leave one gift, but two; the Orionids meteor shower in October is also a leftover (Ventrudo 2015) (Chap. 10).

Mind's Eye Target: Halley's Comet

Though it was last seen in 1986 in the inner solar system—and will return to being a bright object in 2061—that doesn't mean that Halley's Comet is not in the night sky. It's too faint to see, but it's currently below the constellation of Cancer (Chap. 4). Next time you center your binoculars on Procyon in Canis Major, let you mind's eye see the famous comet on the far left-hand

side of your field of view. It's currently about the distance of Pluto away, and will be traveling in the direction of Procyon for decades yet, passing it line of sight (see below) in 2045 before rushing back into the inner solar system for its next brief performance.

Meet the Grandparents

A globular cluster is the oldest thing you can see in the night sky. A halo of tightly packed stars that looks a bit like a galaxy in its own right—and a truly beautiful sight in a telescope—globular clusters are star clusters that formed and remain in the outskirts of the Milky Way (Chaisson and McMillan 1999), and no longer produce new stars. Astronomers know of about 150 in our own galaxy, which are found far away from the galactic plane. The stars found in globular clusters, such as in the Great Hercules Cluster, are much older, and redder, than stars found in the Milky Way—as much as 13–15 billion years old (Talpur 1997). Star formation would have stopped in these clusters soon after their inception, so only old stars remain (Chaisson and McMillan 1999).

Some globular clusters are named after their shape or appearance, such as Omega Centauri, only viewable from the southern hemisphere (Chap. 13).

Naked Eye Constellation: Hercules and the Keystone

Climbing up from the horizon this month is a major new constellation that you may not ever have seen before. This shape of a man kneeling down, with a club held behind his head with one arm, is tricky to see because it doesn't contain any really bright stars. But an asterism within it called the Keystone holds an important place in stargazing lore (Fig. 5.2). Luckily, this asterism is fairly easy to pick out since it's made-up of the four brightest stars in the constellation; find bright star Arcturus in Bootes and follow a line backward to the north-east horizon—you'll see the Keystone rising. This trapezoid shape is worth finding because of a stunning globular cluster found on its upper right-hand side this month.

Binocular Target: The Great Hercules Cluster, M13

Some think this is the most beautiful sight in the entire northern sky. Though it is best viewed in a telescope, a glimpse of this globular cluster in binoculars is also a must. As the closest and the brightest globular cluster to us in the northern hemisphere, the Great Hercules Cluster (also known as M13) is about 25,000 light years distant. To find it, range binoculars down the side of the Keystone, going a third of the way between the upper star Eta Herculis and Zeta Herculis to its lower-right; you should spy a misty patch that's distinctively bright in the center (Fig. 5.2). You're looking at the combined brightness of as many as a million stars. Later this year we'll take a look at some globular clusters much closer to us—M22 in Sagittarius (Chap. 7) and M71 in Sagitta (Chap. 8).

As a bonus, if you put M13 on the far-left of the field of view in binoculars, on the far-right is an easy line-of-sight double star towards the constellation of Corona Borealis (Chap. 6). These two orange giant stars are 640 and 590 light years from us, respectively, and not physically related (SkySafari 2014).

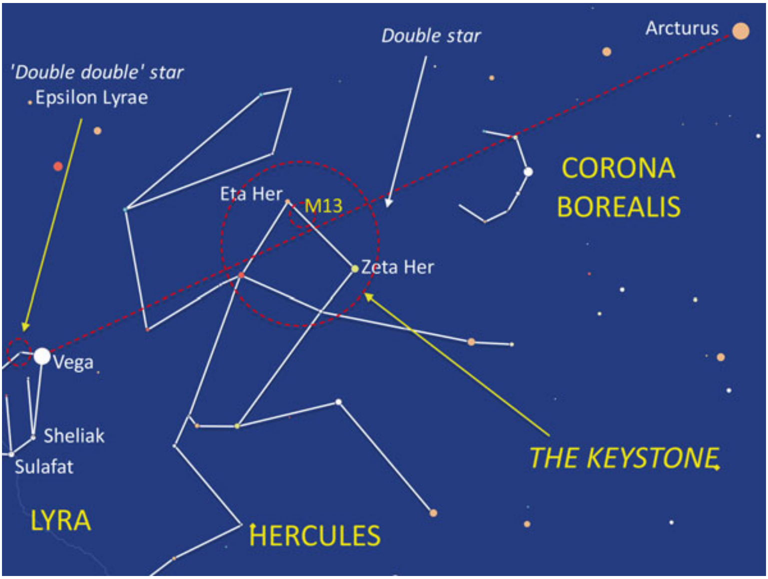

Fig. 5.2 Lyra, Hercules, the Keystone and globular cluster M13

The Empty Quarter

The fact that we can see other galaxies is because we're not in the center of the Milky Way. If we were, the night sky would be thicker with stars and we would be able to see little else. Because of our geographical position at the edge of the not particularly large or important Orion Arm (Chap. 2), we can see into deep space. With the help of telescopes we can see distant galaxies. With the invention of radio astronomy and the launching of space telescopes like Hubble, galaxies can now be glimpsed all over the night sky, even those once obstructed by the center of the Milky Way. However, to stargaze at the Universe beyond means turning to face the Realm of the Galaxies, beneath Leo (Chap. 4) and, nearby, at two more constellations that become visible in May, Coma Berenices and Virgo.

Star-hop to Coma Berenices

This is another tricky constellation to find because it's so small. Coma Berenices is not an imaginative constellation, with just three stars making up an L shape that, at this time of year, is on its side. It's underneath the Big Dipper, sandwiched between Bootes and Leo (Fig. 5.3).

Naked Eye and Binocular Constellation: Coma Berenices

Look at the area of sky high to the east between the Big Dipper, Bootes and the back of Leo. If you're in light-polluted skies, you most likely won't see anything save for bright star Cor Caroli from the Spring Diamond asterism (Chap. 4) beneath the curve of the Big Dipper's tail. Between Cor Caroli and Denebola at the tip of Leo's tail is Coma Berenices, a constellation of just three stars. The brightest star in Coma Berenices is Beta Comae Berenices, the middle star, which is a mere 30 light years distant.

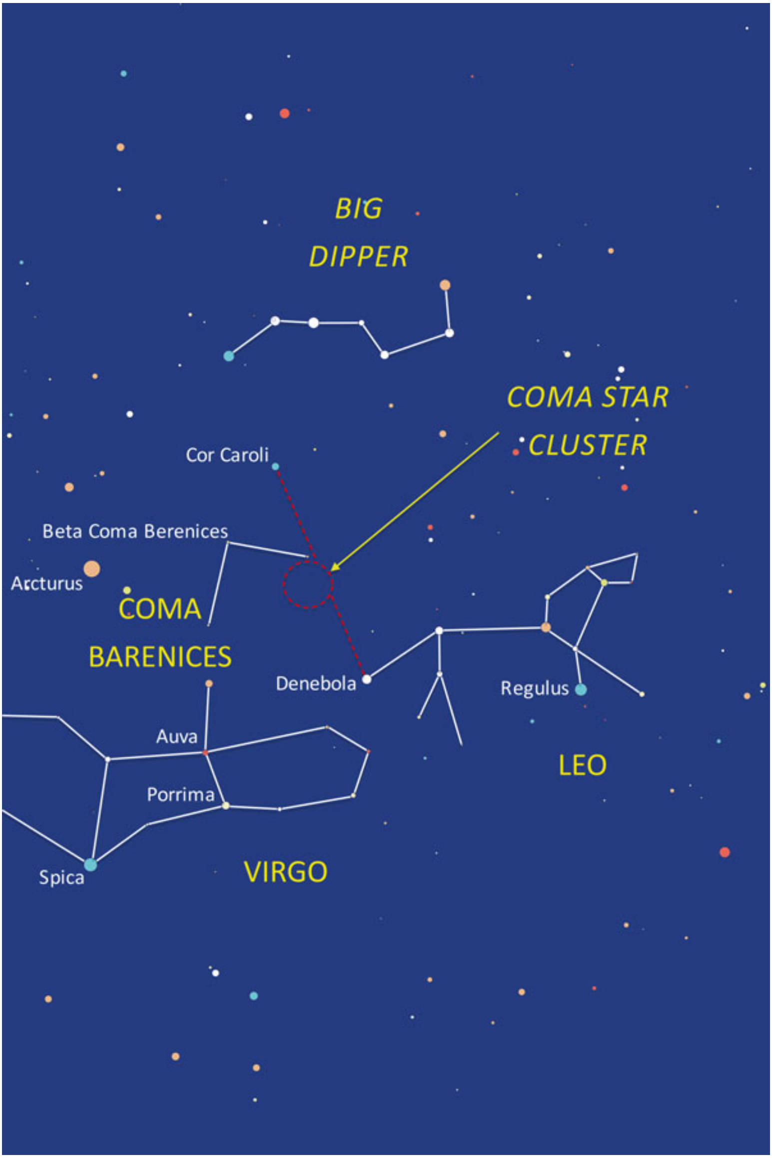

Fig. 5.3 The constellation of Coma Berenices includes the Coma Star Cluster/Melotte 111, a fine binocular target

Binocular Target: The Coma Star Cluster/Melotte 111, Coma Berenices

Sweep some 10× binoculars between Cor Caroli and Denebola, at the tip of Leo's tail, and you'll come across 20 or so bright stars—and many dimmer stars—that are part of an open cluster called the Coma Star Cluster or Melotte 111. At about 288 light years distant, it's one of the nearest star clusters to the solar system. It has a distinct shape; it looks like a football goalpost, or perhaps even a rabbit's face and ears. The Bugs Bunny Cluster, anyone?

Naked Eye Constellation: Virgo

You already know Spica, and how to get to it from the Big Dipper (Chap. 4), but the constellation it's part of often gets ignored. It's reasonably high in the southern sky in May and is easily found, but aside from Spica it lacks bright stars. First find the Spring Diamond using Spica, Denebola in Leo and Arcturus in Bootes (Chap. 4). Travel a third of the way from Spica in the direction of Denebola (Fig. 5.3) and you'll come to Porrima, a binary star a mere 38 light years distant. Just above Porrima is Auva, a red giant like Betelgeuse, though at around 200 light years distant it's much closer than the 640 light years to Betelgeuse.

The Virgo Cluster

Between Coma Berenices and Virgo is the Virgo Cluster, a loose and not particularly well defined collection of hundreds of individual galaxies, with some giant galaxies in the middle. Named solely after the region of sky it's found in, the Virgo Cluster is over 50 million light years from us.

The Milky Way exists in a small cluster of its own, the unimaginatively named Local Group (Chap. 10), which resides in the suburbs of this Virgo Cluster.

The Line of Sight Limit

You'll hear phrases like 'in the observable Universe' a lot from astronomers. It refers to the fact that our telescopes, whether they're on land or in space, can only collect data and make observations from one specific point in the Milky Way. That has huge implications for what we can see and know.

The Unobservable Universe

All of our observations are done from a line-of-sight perspective; if a star, a cluster, a galaxy, cluster of galaxies or a supercluster lies behind something—especially something very bright, like the center of the Milky Way—it can be masked, distorted or invisible. This is the unobservable Universe, and to some extent it occurs in every direction.

Zone of Avoidance

Less used, but critical to understanding the limits to stargazing and astronomy, is the Zone of Avoidance. It describes the fifth of the night sky that is blocked from further investigation by the presence of the stars and dust within the Milky Way. That means that the plane of the Milky Way—the galactic plane—is the most difficult place to search for objects. It's much easier to search and find on the 'other side' of the night sky, which looks away from the Milky Way's center and out into the Universe. It's interesting to think that if the solar system was closer to the galactic center, the Milky Way would not only be brighter in the night sky, but it we would see even less with our telescopes; we'd know far less about the Universe at large.

This doesn't mean that the Zone of Avoidance is to be avoided; it's been a prime target for radio astronomy, which is uncovering much that was hidden from the view of optical telescopes. The Zone of Avoidance still exists, but it's getting smaller thanks to both radio and infra-red astronomy.

The Brightness of Stars

The apparent brightness of stars is crucial in stargazing; if a star is not bright enough for the human eye to see, you're going to be wasting your time trying to find it. Luckily, there's an easy system for working it out—and it all stems from a very special star rising this month to the north-east.

Naked Eye Star: Vega

The fifth brightest star in the night sky, Vega is by far the brightest star in the constellation of Lyra (Fig. 5.2). A blue-white color, Vega is only about 25 light years away. As well as being surrounded by some superb sights and being one of the three stars that make up the Summer Triangle—an asterism you will soon learn to love (Chap. 6)—Vega holds a special position in stargazing. The brightness of all-stars is expressed as magnitude, a sliding scale of brightness that starts with a control star. That's Vega, which therefore has a magnitude of zero. If you don't think Vega is a special star, your ancestors definitely will because Earth's precession (Chap. 6) will mean that Vega will appear to be above the north celestial pole in about 10,000 years (Lunine 2013), replacing Polaris as the north star.

Know Your Limits

The absolute brightness of stars is now measured by space telescopes, but for the purposes of stargazing, we're only interested in what we can see from Earth. This is expressed as visual limiting magnitude, and sets out the boundaries for what you can and cannot see with various pieces of equipment including, crucially, your own eyes. The bigger your optics, the more you can see in the night sky, which is why giant light-gathering telescopes can see so much more than the human eye.

The scale of magnitude is simple, but takes a bit of getting used to. With Vega as the baseline, it follows that anything brighter than it will be easily visible, while stars that are dimmer will become more and more difficult to see. It's slightly confusing in that magnitude is expressed as a negative or

positive number. Stars that are brighter than Vega have a negative magnitude; for example, Sirius has a magnitude of −1.4, the Full Moon −12, and our Sun a whopping −26 (so bright it blocks our view of everything else). Stars less bright than Vega—which is the vast majority—have positive magnitude; for example, Rigel is very similar to Vega +0.1, Betelgeuse is +0.5 and Castor is +1.6.

Star clusters and galaxies also get the same treatment; the Hyades has a visual magnitude of +0.5, the Pleiades +1.6 and the Beehive Cluster is +3.7. The latter is only just visible to the naked eye, but easy in binoculars (Chap. 4), which gives you a clue about how visual limiting magnitude translates to what the naked eye can and cannot see (see below).

The major planets are relatively bright, so have negative visual limiting magnitude, though their exact brightness changes as our distance from them increases and decreases. If a planet is described as being at opposition—a term often used in stargazing calendars—Earth is directly in between it and the Sun; this is the best time for viewing the planet because it is at its brightest as seen from Earth. Its visual limiting magnitude never gets higher.

Say What You See

Visual limiting magnitude is crucial for stargazers because it places limits on what we can see. The human eye is reckoned to be able to see stars down to a visual magnitude of about +6—around 100 times fainter than Vega—but that really only applies in truly dark skies. In your average light-polluted city, the visual magnitude is limited to around +4—and that's with excellent dark adaption.

Knowing the magnitude of a star or planet can help in identifying constellations, and making sense of what you see when you sweep binoculars or a telescope around and within a constellation.

As magnitude increases by a factor of one, you'll see three times as many stars (Harrington 2007). That might mean 10 stars at a magnitude of +2 in

the center of a light polluted city, 30 in the suburbs at +3, and 90 on the outskirts of town at +4. Leave the city limits altogether and the magnitude of stars might increase to +5 or +6, which will uncover between a few hundred and a thousand stars. Here you've reached the limit of the naked eye. Pick-up your more sensitive binoculars and you can suddenly see stars down to a magnitude of as much as +10 (http://www.astrometry.org/magnitude.php)—that's around 600,000 stars—but only in a dark location. Using binoculars in the suburbs of a city will mean a visual limiting magnitude of about +7, which is about 25,000 stars—certainly enough to be getting on with. It's all a trade-off between the amount of light that's collected, and light pollution.

The bottom line is this; if you're looking for an object with the naked eye that's listed as having a visual magnitude of +2 or +3 and you can't see it, you're either under very light-polluted skies or you need more time to allow your eyes to adapt to the dark.

Either way, understand visual limiting magnitude and you'll begin to realize why stargazers like to travel to find darker skies (Chap. 15); visibility of stars rises from double figures in a city to many hundreds of thousands under dark country skies.

Moving Groups

We already know that constellations are simply stars that are line of sight companions as seen from Earth (Chap. 4), but stars rarely travel solo. We've already come across star systems where two or more stars orbit each other, such as Mizar and Alcor in the Big Dipper (Chap. 1). We've also looked at many open clusters, such as the Pleiades (Chap. 2), where stars are moving through space together. They also look close together to us, so referring to them as a group is hardly an intellectual leap. However, there are other, much closer stars that are moving through space together in groups despite seeming—to us—to be on opposite sides of the night sky and in completely different constellations.

The Castor Moving Group

Vega (see above) is part of the Castor Moving Group, a cluster of stars that we're so close to that it doesn't look to be even a loose grouping. It's presumed that these stars formed together in an open cluster. Stars are such vastly different distances from the solar system that constellations are usually a combination of extremely bright, near stars and very dim, faraway stars. Identifying which stars are actually moving together through space is difficult because they're often found on opposite sides of the celestial sphere. That's partly the case with the Castor Moving Group; Vega is accompanied in this group by Castor, in Gemini (Chap. 3), which is 50 light years away from the solar system, and Fomalhaut, (pronounced Fo-maloh), a very prominent star found in the southern hemisphere constellation of Piscis Austrinus (and which is just visible from the northern hemisphere above the southern horizon from September-December). Fomalhaut is 25 light years away from us, the same distance as Vega.

Stellar Motion

Although all of the stars appear to move constantly in the night sky, we know that it's the rotation and orbit of the Earth around the Sun that's causing the four-minutes creep of the stars each day (Chap. 3) and the changing seasonal constellations, respectively. However, stars are themselves moving, too. It's happening so slowly that it's difficult to measure, and you certainly won't notice any stars move in an entire lifetime (with one exception, see below). But they are moving. All the stars in the Milky Way are orbiting the center, including our Sun, which takes about 250 million years to make one complete orbit.

The way astronomers measure space motion is by using Earth's orbit around the Sun to create a parallax; a star's exact position as viewed from Earth is measured six months apart when Earth is either side of the Sun. That's convenient—it means astronomers can go from one side of the solar system to the other without any effort—though it's only a large enough difference to see motion in the very closest stars.

The nearer the star, the easier it is to measure; the fastest-moving star we know of is Barnard's Star in the constellation of Ophiuchus (Chap. 6), which

is just six light years from us, making it the second-closest star we know of after the Alpha Centauri star system (Chap. 13). In an average human lifetime Barnard's Star, a faint red dwarf star (Chap. 8), will move about the equivalent distance of the diameter of the Moon in the night sky. In celestial terms, that is very fast!

Another scenario where stars appear to move slightly is in binary or triple systems, where two or three stars orbit each other. As they pass each other, astronomers can detect a change in the stars' brightness. Such stars are known as variable stars, of which Algol is the most famous—it's even possible to see it blink as the brightness changes (Chap. 11). In May, the easiest multiple star system to see is Epsilon Lyrae, known as the 'double double', in the tiny constellation of Lyra—and it's an absolute stunner. Let's take a look.

A Double Star

We have looked at some 'far' double stars before, when tracing the outline of Ursa Major (Chap. 3), but perhaps the most famous double star of all—Epsilon Lyrae—is rising this month in the tiny constellation of Lyra. Having just found Vega, its brightest member, you may have already noticed it.

Naked Eye Constellation: Lyra

One of the smallest, yet most beautiful constellations of all, Lyra the harp (Fig. 5.2) contains the unmissable Vega. First identify Vega, then, using your binoculars, scan down to two much fainter stars in line. Scan slightly to the right and down, and you'll see a brighter pair of stars called Sheliak and Sulafet. Scan left again and you'll come to the final pair of stars that complete a constellation said to resemble a small parallelogram capped by an equilateral triangle (Dutch 2009).

In Lyra lies the Ring Nebula or M57, the most famous planetary nebula (Chap. 9) in the night sky, but at a visual magnitude of over +14, it's barely visible through an eight-inch telescope. Now rising, Lyra will reach its highest point in August.

Besides the double star we're about to find, there's another reason why stargazing at Lyra has a special significance. NASA's Kepler Space Telescope spent four years between 2009 and 2013 planet-hunting in the direction of Lyra and found over 1000 (Wall 2015) (Chap. 8).

Naked Eye and Binocular Target: Epsilon Lyrae, the Double Double

How good is your eyesight? And how dark is your backyard? Look slightly to the left of Vega and you'll see a star … or is it two? Put your binoculars on this star and, yes, it's definitely two stars. Lying around 180 light years from us, the double double—called Epsilon Lyrae—is a binary star system where two stars orbit each other. For us, for now, that's the story, though a telescope will allow you to split both stars, called Epsilon1 Lyrae and Epsilon2 Lyrae, each into two (Chap. 10). This is quadruple star system where two pairs of stars orbiting each other, also orbit the other pair.

This gem of the summer night sky, easily visible from cities, is ideal for showing others. Splitting double stars without any optical aids is a fun thing to do when you're camping or indulging in a bit of sidewalk astronomy, and there are plenty more to find as the year rolls on. It's stargazing at its purest, but if you wear glasses, just remember to put them on, and note that this particular past-time does get harder as your eyes get older.

Come back to Epsilon Lyrae each month over summer since it will get clearer and better through August.

Twenty-First Century Stargazing

While looking through binoculars on Moon-less nights, you will have seen a lot of odd-looking stars moving slowly across the sky. They're not stars, but satellites. Despite their central place in modern civilization, few ever notice the satellites crossing the night sky—and that's despite one of them being perhaps humankind's greatest achievement.

Satellites

You can easily see more than 10 satellites per hour in the few hours after sunset, or before sunrise. There are over a thousand up there, the nearest taking about five minutes to cross the sky. You'll also see much slower satellites that take twice as long to disappear from view. Most are communications (such as satellite phone coverage), weather or spy satellites.

Stargazers can only see about half of all man-made satellites; the other half are TV, communications and more weather satellites (whose photos we see every night on TV weather reports). They are all in distant geostationary orbits, so remain above a specific point on the Earth's surface. They're too far away to see with the naked eye.

Next time you see a moving satellite, put down your binoculars (and put your glasses on, if applicable) and see if you can spot it with your naked eye. The chances are you can, but only if you know it's there.

Occasionally you'll see a light that crosses from west to east just after nightfall that looks about as bright as Jupiter or Venus (Chap. 4). Is it a satellite? Yes, but not just any satellite—this is one of the closest satellites, and it's usually got six human beings aboard. It is, of course, the International Space Station (ISS), one of stargazing's newest and most dramatic sights (Fig. 5.4).

The International Space Station

It's easy to find and a delight to observe, but few people ever actually witness the ISS passing over despite it being one of the brightest objects of all in a clear sky.

About the size of a football field, it's easy to spot with the naked eye. The ISS streaking across the evening sky is the perfect way to kick-start a stargazing session.

Fig. 5.4 The International Space Station is one of the brightest objects in the night sky. © NASA

What the ISS Looks Like

Although it out-shines stars, the ISS is easily confused with a passing plane. However, while a plane has a white light accompanied by a red flashing light, the ISS is a constant, bright white light. It shines only because its huge solar panels reflect a lot of sunlight. You'll be surprised by its initial brightness; it streaks across the sky in about three or four minutes (and around the globe in just 90 minutes), and moves so quickly through the field of view of a pair of binoculars, fading as it races east and away from the Sun's rays into the night. A bright, constant light that is traveling surprisingly fast, the ISS is unmistakable once you've seen it, but its orbit is rather erratic from our point of view on Earth's surface. Like everything else in stargazing, timing is everything.

When to See the ISS

The ISS is usually invisible because at night it's in the Earth's shadow, and during the day the sky is too bright. It's only visible if it happens to be over your location an hour or two after the Sun has either dipped below the horizon, or is about to rise.

For about 10 days straight you can see it every evening from any one location, but then you'll likely have to wait a couple months for its return to the morning sky, then another couple months to see it in the evening again. And so on. That's not because it's not crossing your location, but that it's doing so in daylight, so is invisible.

Where to Look for the ISS

If the ISS crosses the sky just after sunset, you'll see it appear in the west and disappear from view close to the eastern horizon. However, if it's a couple of hours after sunset, once it's reached the zenith it will be entering Earth's shadow, so it will fade very suddenly and completely disappear from view long before it reaches the horizon. If you're lucky, you might see it twice; the ideal beginning and end to a stargazing session!

The ISS orbits Earth 16 times in any 24 hour period, but since Earth is rotating from west to east and the ISS is orbiting diagonally from south-west to north-east, its path appears to shift north.

If it comes from the south-west, crosses the zenith and disappears in the east, its next pass in 90 minutes will appear in the west and fade in the north-east.

Why to Look for the ISS

Since each time the ISS passes overhead it's on a different trajectory, no two sightings are identical and, besides, correctly identifying it as it crosses the night sky (particularly when you're in an unfamiliar location) is a surprisingly easy stargazing skill to master. It's hugely rewarding, too; being

able to track a man-made object as it orbits the Earth is surely one of the joys of stargazing in the twenty-first century. Once you've seen it whizz from one horizon to the other in just a few minutes, you'll never fail to notice it when it's overhead.

Emails from Outer Space

If you want to know exactly when it's going to be overhead, NASA's Spot The Station[1] service is unbeatable. Simply enter your country, region and city, and wait for an email from Mission Control at NASA's Johnson Space Center in Houston, Texas. Be patient; NASA doesn't send alerts every time it's crossing your location, instead only letting you know those occasions when you're likely to see it more or less overhead. If you want to know who's up there, visit the one-trick website How Many People Are In Space Right Now[2] for the full run-down of who's currently inside the ISS. The excellent Heavens Above[3] website also has exhaustive ISS-spotter pages.

ISS Apps

ISS pass predictor apps are many. Apps like ISS Spotter, ISS Finder and ISS Locator turn a chance encounter with the space station into a regular, predictable event by plotting its progress on a world map. It also checks your own location and produces a list of that month's exactly timed sightings with an optional alarm. That might sound like overkill, but it's also a handy reminder to go outside and start stargazing.

Naked Eye and Binocular Target: The International Space Station

The next time the ISS is due to swing across the night skies above you, go outside with your binoculars and get them focused and calibrated if they're not already. The ISS will appear in the south-west or west of the sky

[1] http://spotthestation.nasa.gov/
[2] www.howmanypeopleareinspacerightnow.com
[3] www.heavens-above.com

and travel across to the east. As it does, track it first with your eyes, and then with your binoculars; you'll be amazed both at how bright it is, and how quickly it moves through your binoculars' field of view against the background of stars. You're looking at something orbiting Earth about five miles per second; that's about nine times faster than a speeding bullet.

Photographing the ISS

This is completely optional—not all stargazers will want to take photos, or have the right equipment (a DSLR camera on a tripod)—but those six-or-so humans are simple to photograph. Since it takes about four minutes to cross the sky, a long exposure photograph using a wide-angle lens can easily capture the bright trail of the ISS. Just don't expect any detail; it's about 250 miles above you.

Where to Point Your Camera

If you have a reasonably low view to the west, you can see the ISS appear over the horizon. The nearer it is to sunset, the longer the ISS will stay bright enough to capture, so you may be able to take one shot facing west of the ISS rising, then swivel your camera and take a second shot of it dipping towards the eastern horizon (Fig. 5.5).

Composing the Shot

The best photos of the ISS are already good landscape photos, with orbiting humans adding an unusual dimension. Try to get some foreground interest, such as the rooftop of your house, grand public buildings or bridges (though avoid anything illuminated at night), or some trees or mountains. Bear in mind that a bright Moon can wash-out the sky in a long-exposure photograph, though that can give the illusion of a day-time pass of the ISS.

If you want to be really ambitious, you have two options. One is to capture the ISS passing a crescent Moon (see below), which can only occur in the western sky so you'll have to capture the ISS almost the second it comes

Fig. 5.5 The International Space Station passes 250 miles above Cardiff, South Wales. © Jamie Carter

into view. The second is to attempt a star-trail photograph that captures the movements of stars (Chap. 8), something that takes over an hour to capture; if the ISS happens to pass over during that time, you might get something really special slicing through your star-trail!

Taking the Shot

The tripod is crucial since you'll be opening the shutter for 30-seconds. With the camera in manual mode and the lens on manual focus and set to Infinity, set the ISO at 400 and the aperture at f/2.8 or lower. Take a test exposure for 30 seconds. When the ISS is due, begin to scan the horizon with your eyes while crouched behind the camera. When it appears, line-up the photo as quickly as possible and open the shutter for 30 seconds. When that's done, swivel the camera so it's facing the east and wait for the ISS to drop into the field of view; even if it begins to fade to the naked eye, your camera will likely still pick it up.

The Crescent Moon

Find out the date of New Moon, and go out hunting for the crescent Moon a day later. Because the Sun is just catching the side of the Moon, it throws long shadows. This makes the week of the First Quarter Moon the very best time to see its craters.

Naked Eye Target: The Crescent Moon

Occurring precisely two weeks after a Full Moon, the New Moon is the term for when our satellite is between us and the Sun—typically above or below it from our perspective—so it's lost in the Sun's glare. It's also invisible because only its unseen side is illuminated. However, go somewhere with a very low western horizon on the day after New Moon and you'll see a tiny slither of a crescent Moon low in the sky just after the Sun has set (Fig. 5.6). It may even be visible during the day, too. A word of warning: if you are trying to find it with binoculars be very careful not to accidentally look at the Sun.

Fig. 5.6 Look at a one day-old Moon and you'll see a super-slim crescent. Credit: ESO/G. Brammer

References

Chaisson, Eric and McMillan, Steve. Astronomy Today, 3rd Ed. Prentice-Hall, New Jersey. 1999.

Dutch, Stephen. Finding Your Way Around The Sky. [ONLINE] Available at: http://www.uwgb.edu/dutchs/astronnotes [Accessed 01 June 15]. 2009.

Harrington, Philip S. Star Ware, 4th Ed. John Wiley & Sons, New York. 2007.

Lunine, Jonathan. Earth: Evolution of a Habitable World Cambridge University Press, Cambridge. 2013.

Southern Stars Group SkySafari [computer software]. Southern Stars Group, LLC. 2009-2014.

Talpur, J. A guide to globular clusters. [ONLINE] Available at: http://www.astro.keele.ac.uk [Accessed 01 June 15]. 1997.

Ventrudo, Brian. See the Eta Aquarid Meteor Shower. [ONLINE] Available at: http://cosmicpursuits.com [Accessed 01 June 15]. 2015.

Wall, Mike. 1,000 Alien Planets! NASA's Kepler Space Telescope Hits Big Milestone. [ONLINE] Available at: http://www.space.com [Accessed 01 June 15]. 2015.

CHAPTER 6

JUNE: THE NIGHT SHIFT

The Stars of June

With the summer solstice towards the end of the month, the nights are long. It's a double-edged sword; with night-fall so late, it can be difficult to fit-in casual stargazing, though the warmer evenings mean being outside is more comfortable.

This month the Sun is moving through the horns of Taurus the bull, blocking our view of the lower half of the famous Winter Circle (Chap. 2) of stars that are now but a distant memory; the glittering jewels of Orion, the Pleiades and sparkling Sirius have long sunk by sunset, though you might still see Capella in Auriga, and the twins of Gemini, Castor and Pollux, in the western sky during twilight. In the east rises the sparkling Summer Triangle and its treasure chest of stars, constellations and asterisms.

With the arrival of the summer solstice comes the opportunity to consider the mis-alignment not only of the Tropic of Capricorn and Cancer—two more creations of the constellations—but of the ecliptic's constellations, too. This is the zodiac, and there's something strange going on that might make you doubt the accuracy of your star-sign forever.

The Summer Triangle

Who needs Orion? For stargazers, the Summer Triangle is the hot season equivalent of the frosty Winter Circle (Chap. 2), and though it perhaps doesn't quite reach the majesty of Orion and company, it comes pretty close.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_6

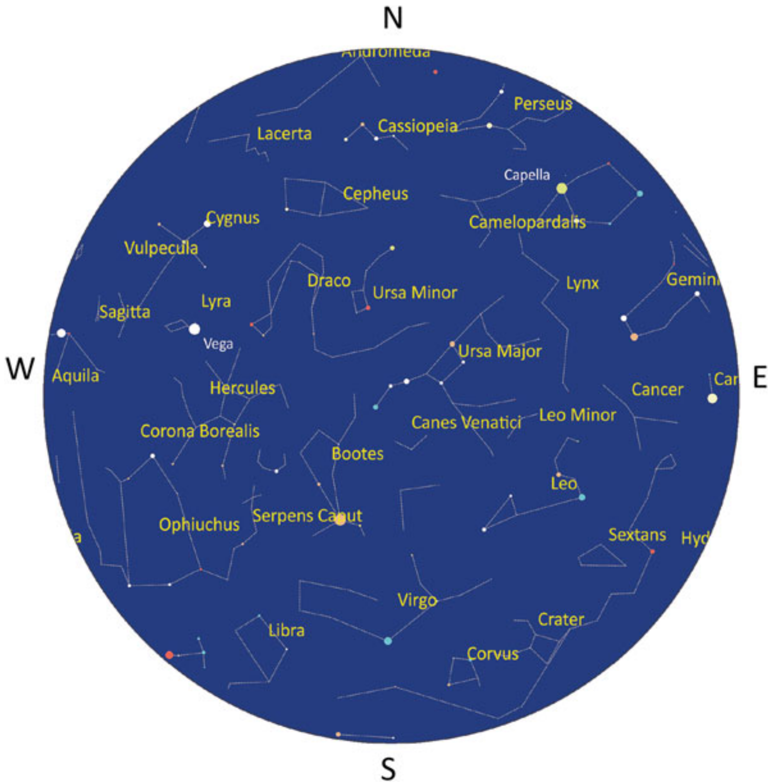

Fig. 6.1 Star-chart for June 1 at 10 p.m.

Naked Eye Asterism: The Summer Triangle

Welcome to your new favorite asterism, the three lynchpin stars of which come to dominate the eastern sky after sunset from mid-June. It's clearly visible by midnight at the start of the month, and at 10 p.m. by month's end. The Summer Triangle is a simple shape, with the top two stars, bright Vega in Lyra and Deneb in Cygnus, forming the top and Altair, in Aquila, the point at the bottom (Fig. 6.2). It rises this month slightly on its side. Vega is 27 light years away, Altair is just 17, but Deneb, in contrast, is between 1400–3300 light years distant. Astronomers are unsure of its exact distance, but the fact that we can see Deneb shows exactly how incredibly far we can see into the night sky with the naked eye. Paired with close Vega

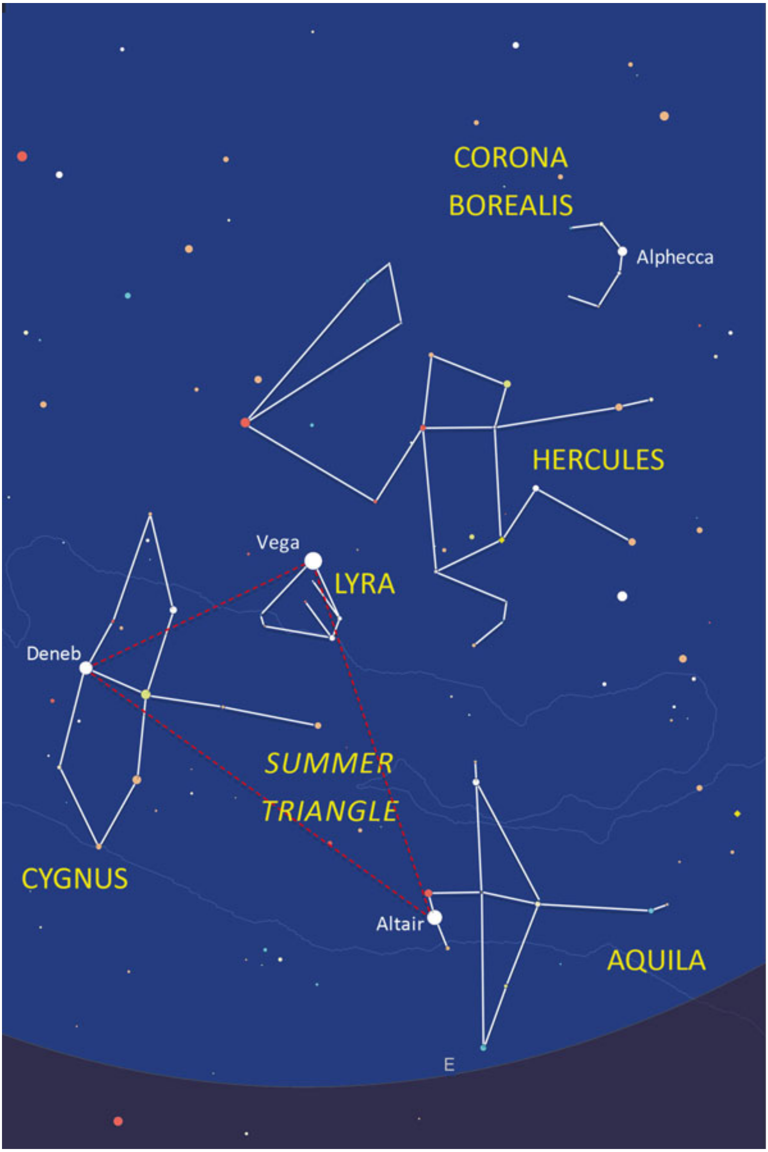

Fig. 6.2 The Summer Triangle dominates the eastern sky after sunset from mid-June

and even closer Altair, Deneb's huge distance shows how lopsided the Summer Triangle really is.

There are gems inside the Summer Triangle that we'll return to over the next six months as the asterism drifts to the south and west and sinks on its side in December, but for now, just get a handle on where it is in the sky. The asterism is actually at its best—high in the south—in late August and September, so should perhaps be called the Fall Triangle. Whenever you go outside this month, look to the east and try to find it; it's our anchor for almost the rest of the year.

Binocular Constellation: Corona Borealis

After looking at the Summer Triangle, it's worth casting your binoculars back to the Great Hercules Cluster (Chap. 5). Just beyond it is Corona Borealis, an arc of six stars between the constellations of Hercules and Bootes. A constellation in its own right despite its tiny size, Corona Borealis—also known as the Northern Crown, and understandably thought of as a boomerang by Aboriginal Australians—contains a crown jewel in the shape of the brightest star, Alphecca (or Alpha Corona Borealis), which is just 78 light years away (Fig. 6.2).

Northern Exposure

With the ever-changing sky to the east and south, it's easy to ignore the circumpolar stars and constellations in the north. However, they're movements are just as seasonal, and there's still plenty more to discover around Ursa Major.

Naked Eye Constellation: Canes Venatici

In comparison to Ursa Major, this little-known constellation is so small that it's hardly worth knowing about, but it will help you find some interesting night sky sights in the vicinity. It's easy to find because it's made up of just

two stars. Just find the brightest, Cor Caroli, by tracing a line to the horizon from Alkaid in the Big Dipper to Denebola at the tip of Leo's tail (Fig. 6.3). Cor Caroli—which is 110 light years distant—is about two-fifths of the way down that line from Alkaid.

Binocular Asterism: The Baby Giraffe Near Cor Caroli

The official constellation of Camelopardalis—the giraffe—is between the Big Dipper and the horizon this month, but it's very faint throughout the year. However, there is another, smaller giraffe in the night sky. Put Cor Caroli in the bottom-right of the field of view in binoculars and look for four stars in the top-left corner arranged in the shape of a giraffe. Directly below those four stars—and pointed at by the giraffe's front leg—is a nice double star. The two stars, 17CvN and 15CvN, are 200 and 1200 light years distant respectively, so completely unrelated. Much like Camelopardalis and my Baby Giraffe, which we'll nevertheless call Camelopardalis Minor (Fig. 6.4).

Mind's Eye Target: The Hubble Deep Field

Originally taken in 1995, this 10-day exposure of a seemingly empty part of the night sky is staggering because of what it includes; hundreds of distant galaxies dating back almost to the beginning of the Universe over 13 billion years ago. This is time-travel at its most staggering, and to find them Hubble had to be pointed both away from the Milky Way, and in between stars so that nothing blocked its view. Find Megrez on the top-left of the bowl of the Big Dipper, then go to the next star along in the handle, Alioth (Fig. 6.3). Make an equilateral triangle pointing above the Big Dipper, and you'll notice nothing. Aside from a few dim stars, there's not much here, but it's precisely where Hubble found those dizzying numbers of galaxies (The Sky At Night: Hubble, The Five Greatest Images of the Cosmos, 2015).

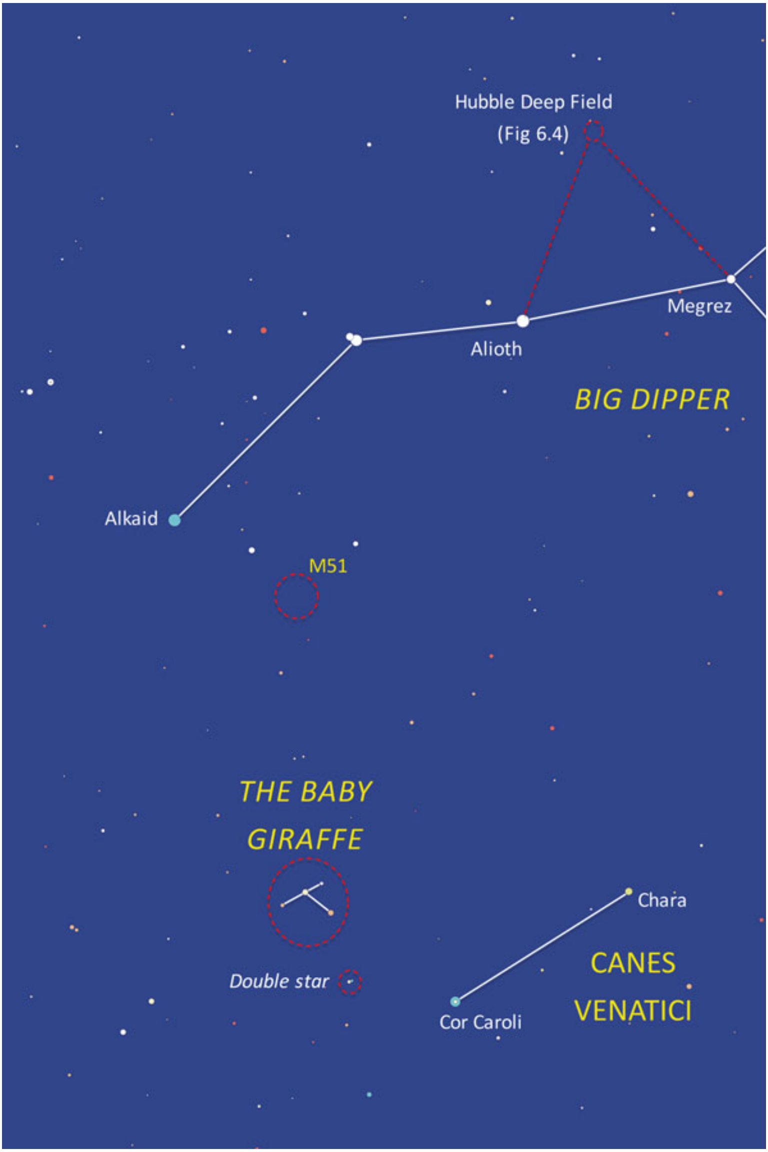

Fig. 6.3 Canes Venatici, the Baby Giraffe, a double star, and the location of the Hubble Deep Field

Fig. 6.4 The stitched-together images that make-up the Hubble Deep Field of 1995. Credit: Robert Williams and the Hubble Deep Field Team/NASA

The Hubble Deep Field was followed in 2004 by the Hubble Ultra Deep Field[1] and in 2012 by the Hubble eXtreme Deep Field,[2] both of which showed a similar treasure trove of galaxies, this time in the direction of the southern hemisphere constellation of Fornax (Chap. 13).

The Summer Solstice

Everyone knows that the summer solstice, which happens on June 20 or 21 each year, is the longest day of the year. As such, it marks probably the worst day of the year of stargazing since from high northern latitudes is doesn't get properly dark until the early hours of the morning. However, it also marks the point where the night begins to fall earlier, and to lengthen.

[1] For more information and images see: http://apod.nasa.gov/apod/ap140605.html

[2] For more information and images see: www.nasa.gov/mission_pages/hubble/science/xdf.html

How the Summer Solstice Works

The summer solstice isn't a stargazing event as such—nothing visible happens that makes it different to any other night—but it's an important marker in the orbit of our planet. Since Earth's orbit of the Sun determines what stars we see, and when, the summer solstice is an important way-marker in the stargazing year.

To understand the solstice you need to think about the tilt of Earth, spinning on its axis at 23.5°, and how that influences where the Sun will rise. Since the Earth's axis is tilted towards the Sun, the northern hemisphere gets more sunlight. The Sun appears to shine above the Tropic of Cancer, high above the equator. Compare this with the spring or vernal equinox in March (Chap. 3), where the Sun appears to shine above the equator. On this day the point of sunrise is as far up the eastern horizon as it ever gets, ditto for the sunset point.

From June onwards the Sun will move further south in the sky, with days getting shorter until it crosses the equator again at the fall equinox in September (Chap. 9). The Sun then appears to move further south, culminating in December's winter solstice when it shines above the Tropic of Capricorn (Chap. 12).

Precession of the Equinoxes

In stargazing, things change slowly, but they do change. For instance, Polaris won't always be the North Pole star since the Earth—caused by the gravitational forces of the Moon and Sun—wobbles on its axis, and so gradually points to a different star in a circular motion that last for 25,800 years; pole stars are therefore transient. That long-term wobble also has an effect on the equinoxes because the Sun's apparent path through the sky shifts slightly. The result is that the exact position of the background stars at each solstice and equinox changes over the years.

The Tropics

The Tropic of Cancer and the Tropic of Capricorn are named after the constellations that the Sun is in during the summer and winter solstices, respectively. However, precession has seen the constellations appear to shift so much that the names no longer make any sense. If we were to re-name them accurately, the northern hemisphere would get the Tropic of Taurus and the southern hemisphere the Tropic of Sagittarius. It's the first clue that there's something gone awry in the night sky that most of the world seems oblivious to.

The Zodiac

The location of the ecliptic is always worth contemplating while stargazing, but it's also worth knowing about the zodiac. It's defined as the group of constellations that lay behind the ecliptic; if you draw a line from Earth through any part of the ecliptic and far beyond, it will point to one of the zodiacal constellations. While as a popular concept it may appear to have more to do with astrology than astronomy, thinking about the zodiac takes what you instinctively know—your star-sign—and gives it a real place in the night sky.

The Origins of the Zodiac

Ancient Babylonians, who lived more than 3000 years ago in Mesopotamia in the Middle East, defined the signs of the zodiac from observing the night sky, perhaps shoe-horning them into their existing lunar calendar. Curiously, some of the same constellations appear in totally separate cultures. The zodiac has, or had, a deep meaning in human culture throughout the ages.

The Zodiacal Constellations

There are 12 signs of the zodiac,[3] which are all themselves officially recognized astronomical constellations; Aries, Taurus, Gemini, Cancer, Leo, Virgo,

3 Greek for 'circle of animals'.

Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces. We've already found some of them in the night sky, but it's the position of the Sun in one of these constellations that determines the current sign of the zodiac, so you cannot see the corresponding constellation at night.

Each applies to a specific period of time (around a month) in the calendar. For instance, Leo lasts from July 23—August 22 each year, and those dates don't ever change. They're best remembered using this mnemonic; All The Great Constellations Live Very Long Since Stars Can't Alter Physics. Neat, tidy, and easy to remember, though there is one small problem; it's all completely wrong. You can see exactly why by looking to the west just after sunset this month (see below).

Naked Eye Constellation: Gemini

The star sign of Gemini officially begins on May 22 and will end on June 21. By definition you shouldn't be able to see much of this zodiacal constellation because the Sun should be residing within its boundaries. That makes sense; we were looking at Castor and Pollux in Gemini during the early months of the year when we searched for the Winter Circle (Chap. 2), so it's now on almost the opposite side of the sky. However, Gemini is visible in early June. It's sinking into the twilight for sure, but neither Castor nor Pollux are obscured by the Sun's glare (Fig. 6.5), and nor is the rest of the constellation. The reason is simple; the Sun is actually still in Taurus in early June. The constellation and the star sign are at odds; astrologers have it all wrong.

Astrology and Stargazing

Astrology says that a person's characteristics and future can be foretold using a map of where the Sun and planets were on the day of their birth. This is a horoscope.

That practice may be much derided by astronomers, but the ancient practice of astrology does have its basis in celestial mechanics. However, by observing the zodiac's inaccuracies with the naked eye, stargazers can learn about the true workings of the night sky.

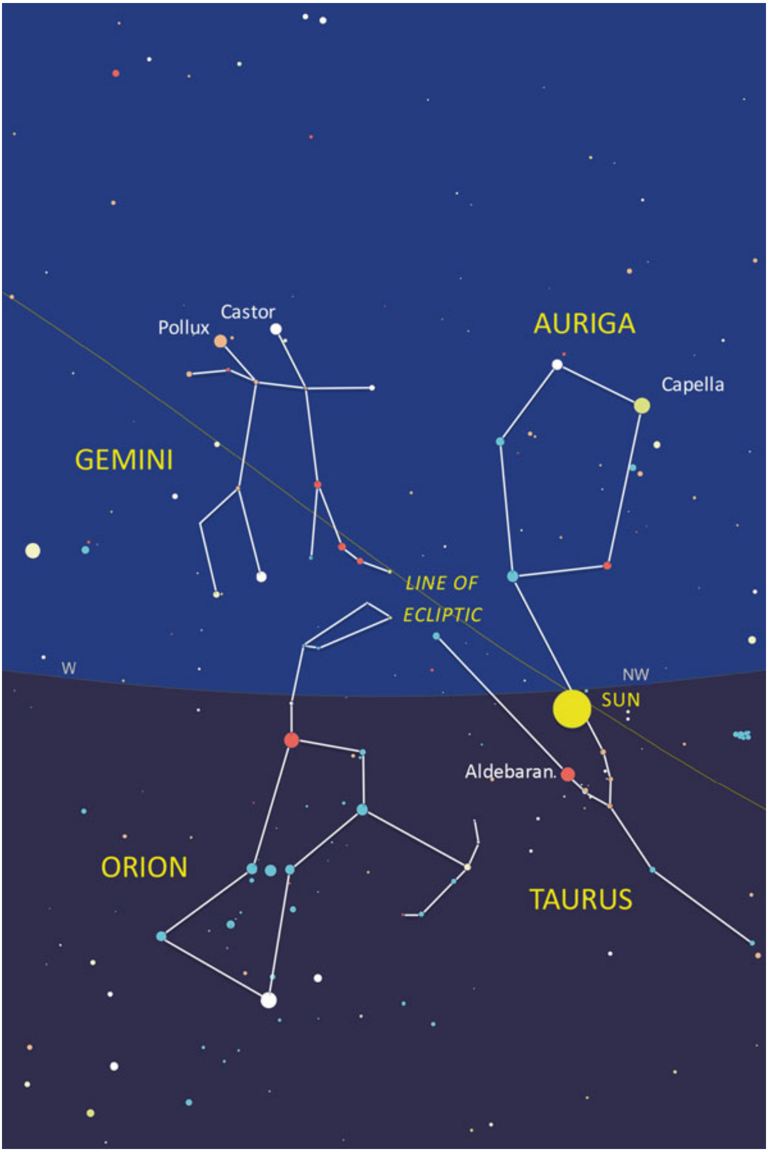

Fig. 6.5 While the star sign of Gemini rules in June, the Sun is actually still in Taurus

Astronomy vs. Astrology

The zodiac is as important to astronomers and stargazers as it is to astrologers, but don't confuse science with ancient beliefs. While astronomy is the scientific study of planets, stars, galaxies and other celestial bodies, astrology is a belief in horoscopes. It's why you might hear people say "he's a typical Leo" about someone who is ambitious.

Astrology's Inaccuracies

Although it's based on actual constellations in the night sky, astrology makes a lot of errors. Stargazers know that the constellations, and the appearance of planets and the Moon within them, are merely line-of-sight views from Earth; when Jupiter is in Virgo, it's actually nowhere near the stars of Virgo. It just looks like it is. Astrology overlooks this, but its biggest mistake is the fixed dates of the star signs. In the process of codifying astrological charts the ecliptic was split into 12 equal parts of 30° each, with each section assigned a constellation. The result is horribly vague. Astrology is about convenient, easy to use horoscopes, with any sense of the interplay between the Sun and stars lost long ago.

Star Signs of Ancients

Modern astrology uses yesterday's sky. While 2500 years ago everything would have more or less agreed with the official dates used by astrologers, the pole star then was Thuban, in the constellation of Draco (Chap. 4), famed for being the north star of the ancient Egyptians. Thanks to precession, Earth's axis now points in a slightly different direction, putting astrology out of sync. Consequently the dates are all wrong, and it's almost certain that you were not born under the star sign you thought you were. For instance, Aries runs officially from March 21 through April 20, but the Sun is actually in Pisces from March 11 through April 18. Astrology now bears no relation to the position of the Sun or stars.

So when you read in your horoscope in the newspaper tomorrow that 'you may grow delusional about a romantic situation' or 'a friend jealous of your

success will try to interfere', don't worry too much; from a stargazer's point of view, a horoscope could only ever be said to have meaning to someone that lived over two Millenia ago in southern Iraq.

The bad news for astrology is that Thuban will appear to shift further from the north pole until about 10,000 AD, not returning to its status as pole star—and the lynchpin of astrology—until the year 20,346 AD. Don't forget to check your horoscope then!

Stargaze Your Star-Sign

As we saw with Gemini (above) this month (Fig. 6.5), because the assigned dates of the zodiac are so badly outdated it is now possible to see the zodiacal constellation of your birth on your birthday. An easy way of finding out what star sign you were actually born under is by using planetarium software and rewinding the date. Look at where the Sun is; is it within the boundaries of the correct constellation? It probably isn't. I'm supposedly a Capricorn, which officially runs from December 22 through January 19, and I was born on January 8, when the Sun was bang in the middle of the constellation of … Sagittarius! The Sun was actually very close to the Galactic Center at the time. I wonder if that gives me special powers? If it does, I haven't noticed any yet. Seriously though, the Sun doesn't technically enter the boundary of Capricorn until January 18, leaving around February 17. But astrologers work on the basis that Capricorn ends on January 19.

It's easy to find out which star sign you were really born under, but if you think you're a Sagittarius, you could be in for an even bigger shock.

The Orphans of Ophiuchus

That modern astrology fails to take account of how the night sky has changed in the last 2500 years is one thing, but it has always missed out one huge constellation on the ecliptic. Either ancient astrologers couldn't stomach an unlucky thirteenth constellation, or they wanted to keep things tied loosely to the 12-month lunar calendar they were already using. Either way, Ophiuchus (pronounced 'off-yew-kus') is little-known.

While I am a Capricorn by astrology and a Sagittarius by the stars, my wife, who thinks she is a Sagittarius, is nothing of the sort. She was born on December 6, and since the Sun was in Ophiuchus from November 30 to December 17, that makes her an Ophiuchan. You won't find it on most zodiacal calendars, but this missing thirteenth star-sign is officially recognized by astronomers as a zodiacal constellation.

So that mnemonic should actually go something like this; All The Great Constellations Live Very Long Since *Old* Stars Can't Alter Physics.

Naked Eye Constellation: Ophiuchus

Ophiuchus is found close to the Summer Triangle, specifically to its right-hand side underneath the constellation of Hercules (Chap. 5). Consequently, it's harder to see the further north you stargaze from. The basic shape of a house with a pointed roof—a little like the constellation of Cepheus (Chap. 11), only larger—can be seen in the south this month. The brightest star, and the peak of the roof, is giant Rasalhague just 47 light years distant, which forms a rival to the Summer Triangle using two of its constituent stars, Vega and Altair (Fig. 6.6). That's a really easy way in to start looking for the stars of Ophiuchus.

Take a line from Vega through Rasalhague and go the same distance again and you come to the second-brightest star in Ophiuchus, Sabik, which lies at the bottom-right of the house shape. Sabik is 88 light years distant.

Mind's Eye Target: Barnard's Star

At a magnitude of +9.5, it's beyond the reach of binoculars, but it's worth knowing about a special star in Ophiuchus, and why it shouldn't be ignored. Just underneath Rasalhague is Barnard's Star, a mere six light years distant. Its fame comes not only from being the second-closest star system to our Sun (the nearest being the Alpha Centauri star system, Chap. 13), but also from its speed. One of the few stars that appears to move in the sky, Barnard's Star will be a mere 3.8 light years from us by the year 11,800 (Kaler 2015).

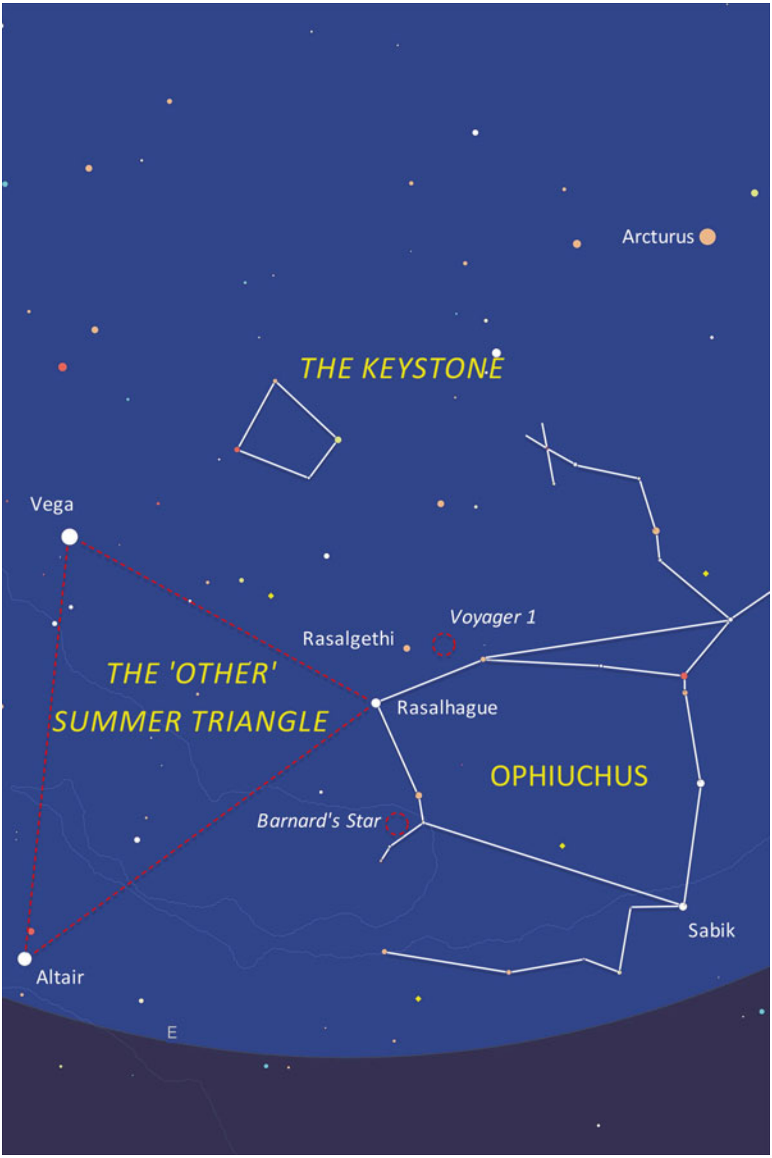

Fig. 6.6 Ophiuchus, Barnard's Star, and Voyager 1's rough position

Mind's Eye Target: Voyager 1

There's something else special about Ophiuchus; it's the patch of sky that the Voyager 1 space probe is traveling through. Voyager 1 was launched in 1977 as part of NASA's Grand Tour of the solar system, and took photographs of Jupiter, Saturn and their moons before continuing its journey. It's now outside the solar system and just into interstellar space—around 130 AU from Earth (for a definition of AU, see Chap. 7)—and the furthest traveled human-made object of all.

At the size of a motor car, it's way too small to see, but find Rasalhague at the top of Ophiuchus, then nudge to the right to find Rasalgethi at the foot of Hercules (Fig. 6.6). Voyager 1 is just below this red giant. Its sister probe, Voyager 2, followed a different trajectory and is now in the southern hemisphere constellation of Pavo (Chap. 13).

The Secret Calendar

Get hold of a lunar calendar. Usually a pictorial guide to the phases of the Moon by day, they do look slightly odd hung on a wall, but a lunar calendar gives you an at-a-glance guide to when is good for stargazing, and when is not.

A lunar calendar can be helpful in avoiding scheduling stargazing sessions—or trips to any dark sky places where where stargazing could potentially be stunning—during the brightest Moon phases when the stars are washed-out.

Check with the Moon

When planning stargazing sessions to dark skies (Chap. 15), avoid the week between Last Quarter Moon and Full Moon, though the few days either side will feature a bright Moon in the sky, too. Having a Lunar calendar handy can help you make a snap decision to the question 'when shall we go on vacation?' without having to utter the (often unexpected!) words "let me check with the Moon".

The Stargazing Window

When planning holidays to rural or backcountry areas where I might want to stargaze for an hour or so in the evening, I try to travel in the period three days after Full Moon until about four days after New Moon, which is a window of only 16 days. Buy a calendar and cross-out days when the Moon is going to be Last Quarter or Full. This doesn't mean you can't stargaze during this time—they may be the only clear nights of the month (they often are!) and many stargazers like these nights the best. However, looking for new constellations and faint objects can be too difficult when the Moon is bright. It's worth putting an asterisk beside sunset on the day of the Full Moon; Moon-rise is a spectacle you should never purposely miss (Chap. 8). Moon-set at dawn the following day can be equally as spectacular.

Photographing the Night Sky

The web is full of great pictures of the stars—just visit NASA's website—but taking your own wide-field images of constellations can be hugely rewarding. Many people think that photographing the night sky requires expensive gear. It doesn't, and although the results you'll get will be basic compared to Hubble's latest shots of deep space, even the simplest of night sky shots can impress simply because a camera finds more stars than your own eyes. Keep your ambitions reasonably low; we're going for wide-eyed landscape shots here, not close-ups of the Moon or planets. For those you would need an expensive telescope and an equatorial mount (Chap. 9) that tracks the motion of the night sky. However, capturing constellations with basic gear requires only patience and some simple techniques (Fig. 6.7).

What You Need

Night sky photography requires a camera with a mode that allows you to keep the shutter speed open for long periods; since it's dark, you'll need to take long exposure images, though none longer than about 25 seconds. Any DSLR is perfect for photographing the stars, though a compact camera with a firework mode can also work well. A tripod is necessary (keeping your camera completely still is critical so don't attempt to hand-hold it), though a small, portable model is fine.

Fig. 6.7 Wide-field images of the night sky can capture the Milky Way. © Gill Carter

Preparing Your Camera

There's nothing worse than fiddling with camera settings outside in the dark, so it's best to get everything set-up inside. Photographing constellations is all about keeping the shutter open long enough to allow the light to enter the camera, but not so long that the stars' apparent motion (actually the Earth's rotation) causes them to blur (about 25 seconds).

Set the aperture as wide as it will go to let in as much light as possible. If there's a light nearby that you can't switch-off, push the aperture up, which will let less light into the camera. Switch the lens to manual focus and fix the focus on infinity. You can pre-set this while it's still light by focusing on a far away point and then fixing the lens so it cannot be adjusted. On a compact, try using mountain mode. Then set the ISO at 400 or 800 (you can experiment with higher settings, but noise can be a problem) (Fig. 6.8).

Fig. 6.8 The Moon makes a good subject for photography at sunset or sunrise when it's less bright. © Jamie Carter

Find a Dark Place

The ambient light makes a huge difference to the end result, so the darker the location, the better. However, that doesn't mean you have to run for the hills, Your backyard is fine if you prepare it well by switching-off all the lights inside and out.

Composing the Shot

A shot of Cassiopeia on its own is a good result, but a photograph of it between two tall trees is even better. Buildings, lakes, trees, mountains … all serve as excellent foregrounds and frames (Fig. 6.9). How much of the foreground you can photograph will depend on your lens; the wider the angle, the more of the landscape you'll be able to get. Photographing a

Fig. 6.9 A building in the foreground can help composition of night sky images, though any uplighting is magnified during the long exposure. © Gill Carter

landscape and stars on the horizon rarely works because stars in that area of the sky look dimmer (the exception is a bright planet like Venus or Jupiter). Try to get close-in to your subject and shoot upwards. Wide-angle shots are best taken using a 10–22 mm lens or similar.

Taking the Shot

Simply pressing the shutter release button introduces enough judder to ruin any long exposure image, so be sure to activate the camera's self-timer function. A two-second delay is fine. DSLR owners may have a remote shutter release cable for the same purpose. While the shutter is open don't be tempted to switch on your flashlight or play with your smartphone—it will degrade your image.

Experiment with Settings

Experiment with shutter speeds of between 10 and 25 seconds. If the results are too dark, use a longer shutter speed and increase the ISO. If the photo has too much light in it, decrease the shutter speed and the ISO. Doing the latter will reveal the colors of stars and reduce unwanted noise in your photos.

Reviewing the Results

Your images will need editing, and your blurry images discarding (it happens!). Cropping may help to produce a better composition. Also try increasing the exposure and contrast in post-processing software such as Photoshop, GIMP or Lightroom. You'll probably find that your camera has captured many more stars than you could see, and perhaps even the Milky Way if you were somewhere really dark.

References

Kaler, Jim. Stars. [ONLINE] Available at: http://stars.astro.illinois.edu/sow/sowlist.html. [Accessed 01 June 15]. 2015.

The Sky At Night: Hubble: The Five Greatest Images of the Cosmos. Television program. British Broadcasting Corporation, London, April 2015.

CHAPTER 7

JULY: DEEP SOUTH

The Stars of July

Your latitude won't just affect how late you must stay up to stargaze this month. Those living below 50° north will get the chance to glimpse the sparkling star fields of Sagittarius and Scorpius, with the latter's orange star Antares—the 'rival of Mars'—the marker. This is the busiest region of the night sky, with countless stars, clusters and nebula. Why so busy? This is the Galactic Center in the middle of the Milky Way, which pokes its head just above the horizon for northern hemisphere viewers. If it's in the haze where you are, it's a great excuse to travel to more southerly latitudes (Fig. 7.1).

Royal Stars

June and July sees the appearance of Antares, a red supergiant star with a special reputation among ancient stargazers. It's a member of the Royal Stars of Persia (Bobrick 2006), four stars of roughly equal brightness that lie on four equally-spaced points of the ecliptic. The other three are Aldebaran in Taurus (Chap. 2), Regulus in Leo (Chap. 3) and Fomalhaut in the southern hemisphere constellation of Pisces Austrinus, which peeks above the southern horizon in October below Aquarius (Chap. 10). Their significance comes from their positions near the Sun on the dates of the solstices and equinox. For example, the Sun was in Leo during the summer solstice (Chap. 6) so Regulus was dominant. With precession (Chap. 6) this no longer applies, though the equal spacing of the Royal Stars remains visible; at the summer solstice Regulus appears just above the south-west horizon, while at the winter solstice Fomalhaut is visible in the same area (though it's very low on the horizon). At the vernal equinox (Chap. 3) you'll find Aldebaran in the south-west, and during the fall equinox (Chap. 9)

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_7

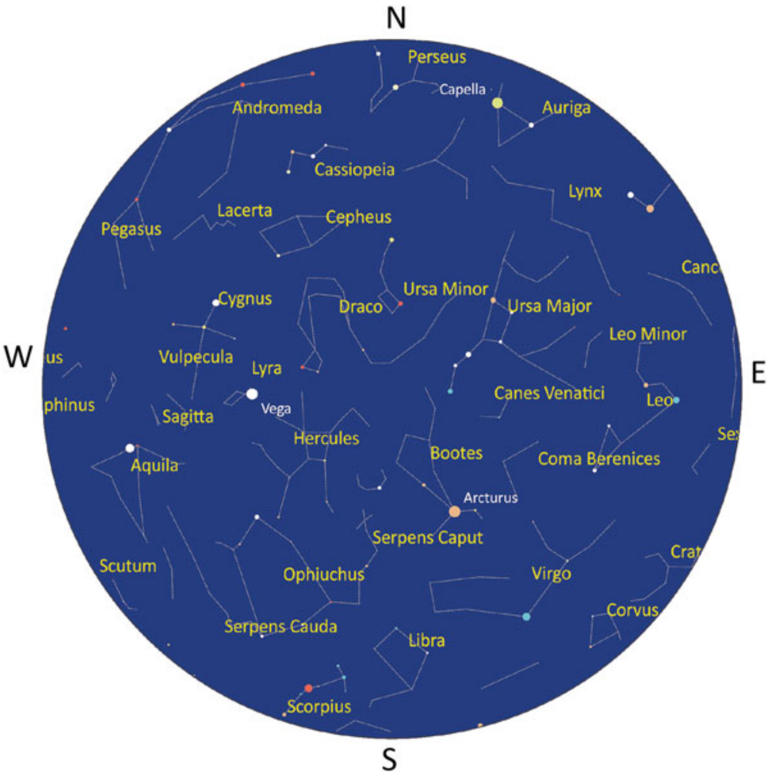

Fig. 7.1 Star-chart for July 1 at 10 p.m.

you'll find Antares there. If you have a good low south-west horizon it's another way to track the seasons.

Naked Eye and Binocular Target: Antares

Look below the star Sabik at the bottom left-hand corner of the constellation of Ophiuchus (Chap. 6) and you'll see bright Antares just above due south. You'll likely have to fight for it in the horizon, but a pair of binoculars ought to find it if you have a low enough view, especially if you're observing from southerly latitudes.

Around 550 light years distant, Antares is one of the biggest stars we know of. A red supergiant, it's often confused with Mars because of its metallic orangey-red appearance (especially through binoculars) though it's slow-moving Saturn (Chap. 9) that is nearby from 2015 until about 2021. Antares is best seen from June–September, and is yet another double star system; it's worth returning to Antares with an eight-inch telescope later in the year if you want to glimpse its much smaller, green-looking companion.

So big is the primary star of Antares that it would stretch to the orbit of Mars if it was put at the center of our solar system (Sessions 2014). As well as being big, Antares has even more in common with Betelgeuse (Chap. 2) in that both are very young; Antares is just 12 million years old to Betelgeuse's 10 million years. Antares belongs to the Scorpius-Centaurus Association, a loose grouping of relatively close stars in Scorpius and Crux, the latter constellation of which is only visible from the southern hemisphere (Chap. 13).

Binocular Target: Globular Cluster M4

Positioned very close to Antares, M4 is one of the easiest globular clusters (Chap. 4) to find with your binoculars; first find Antares, then move two Moon-widths to the west. At around 13 billion years old and 7200 light years away, it's one of the oldest and closest globular clusters. It looks like a fuzzy patch, and not a particularly bright one, but to come face to face with a globular cluster is really special. Return to it with a small telescope and you'll begin to see individual stars; there's over 100,000 here.

Until 2003 it was thought that globular clusters didn't ever contain planets, but searching in M4, astronomers using the Hubble Space Telescope found a Jupiter-sized planet orbiting two dead stars (NASA 2003). More than twice as old as Earth's 4.5 billion years, it remains the oldest planet found and suggests that planets formed within 'just' a billion years of the Big Bang. The conclusion is profound; the Universe is full of planets, and always has been.

Brief Encounters

From a stargazing point of view, the Royal Stars' position on the ecliptic means only one thing; they're ripe for being both passed closely by the planets and blocked from view by the Moon. The former is called a conjunction (Fig. 7.2) and the latter an occultation, and they're well worth looking out for on an astronomical calendar.

Occulting Made Easy

An occultation is when one celestial body moves in front of another, which can be an interesting event to watch. The Moon is constantly doing this with stars, but it's most useful for stargazers when planets are involved. For example, with the Moon next to Uranus, the distant and dim seventh planet is much easier to find. You thus get to use the Moon as a handrail (Chap. 9) for pointing your eyes, binoculars or a telescope.

Fig. 7.2 The Moon in conjunction with Venus and Jupiter. Credit: ESO/Y. Beletsky

Fig. 7.3 Thin crescent Moon setting over ESO's Paranal Observatory in Chile while in conjunction with Mercury and Venus. Credit: ESO/B. Tafreshi (twanight.org)

However, occultations of planets by the Moon are relatively rare and can only be seen from specific places on Earth for short periods of time, usually just a few minutes.

Catching a Conjunction

Less precise, but just as beautiful to look at is when two or more celestial bodies appear close together in the night sky for one or two evenings. This apparent celestial near-miss is called a conjunction (Figs. 7.2 and 7.3), and like an occultation it's nothing more than a line-of-sight alignment, only looser. Rarer are conjunctions of two planets,[1] though over the course of time complex super-conjunctions are inevitable.

[1] The exception being the inner planets, Mercury and Venus, which often appear to be very close to each other just before sunrise and just after sunset.

Super-Conjunctions

A great benefit of having planetarium software is the chance to fast-forward the sky. Not only can you see what's going to be in view tomorrow, next week or during your next planned vacation, but you can go hunting for rare celestial gems. One such gem occurs on September 8, 2040 when the western horizon after sunset will be studded with no fewer than five planets visible in the same area of sky along the bottom of the constellation of Virgo. This is what's called a super-conjunction. They won't be perfectly aligned, but it's near enough; Mercury will be nearest the horizon followed by Jupiter just above it and, just to the south-west, a one-day old crescent Moon will appear to shield Saturn, Venus and Mars. It promises to be quite a sight, and a date for the long-range stargazing diary alongside solar and lunar eclipses. However beautiful and fleeting a conjunction can be, it's crucial to remember one thing; they have absolutely no celestial significance.

Rivals in Red

The brightest star in the constellation of Scorpius, Antares is on the ecliptic. All of the outer planets appear to pass close to Antares at some point, so why the confusion with Mars? As well as Antares and Mars both being orangey-red to look at, its 687-day orbit—by far the shortest of all the outer planets—means that Mars passes close to Antares less than once every two years. Jupiter is close to Antares once every 12 years, while Saturn every 29 years.

Naked Eye Target: Mars

If the brightness of most stars doesn't change, that's certainly not true of Mars. Since it's the next planet out from Earth, the red planet can sometimes be very close. When Earth is between the Sun and Mars, we're just 35 million miles from it so it is the best time for Mars rovers, surveyors, satellites (and perhaps in future, humans) to be launched to take advantage of this narrow window of opportunity. It makes the journey as short as possible. The reason is simple; when Mars is on the opposite side of the solar system to Earth,

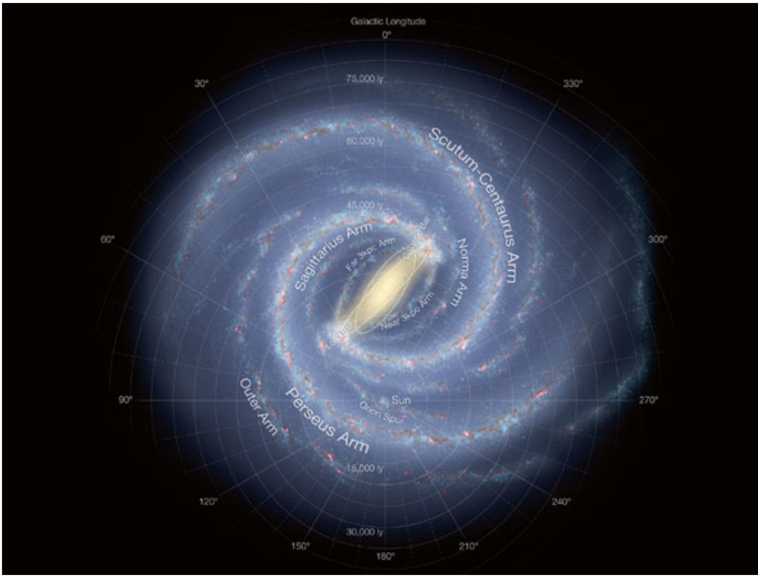

Fig. 7.4 The Milky Way is several spiral arms of giant stars, with the Sun in the Orion Spur (just above the Perseus Arm on this diagram). Credit: NASA/Adler/U. Chicago/Wesleyan/JPL-Caltech

it's 250 million miles distant, so if any humans do ever travel to Mars, they won't return for at least 18 months, when it's nearer.

Its vastly differing distances from Earth means that the brightness of Mars appears to noticeably wax and wane in the night sky. However, since it's further from the Sun than the Earth, we never see it as a crescent, as we do Venus and Mercury (see below). Through a pair of binoculars Mars looks red, and not particularly impressive; return with a small telescope (Chap. 11) and it's possible to see surface markings and ice-caps when it is near.

Galactic Geography

The Milky Way is a confusing place. It's a barred spiral galaxy, which means that there's an oblong-shape bar or bulge of stars, with several arms—all star-forming regions—in the galactic disk that spiral around the center (Fig. 7.4).

We've already looked in winter at the Orion Spur (Chap. 2), and next month we'll visit the Sagittarius Arm while looking at the Summer Triangle (Chap. 8). We'll also come across the Perseus Arm before too long (Chap. 11). However, it's best to not become too obsessed about exactly which spiral arm is where in the night sky when looking in the direction of our next targets, Sagittarius and Scorpius. Here lies the Galactic Center, but the view towards it is through parts of several inner spiral arms that become impossible to pick apart in the middle. However, some basic geography is still useful to put what you're seeing into context.

Southern Star-Fields

As spring's scant-looking constellations are displaced by the stars of summer, some particularly rich and dense star-fields swing into view. Cygnus we'll look at below, but for now try to get a fix on two key constellations of the zodiac (Chap. 6), Sagittarius and Scorpius. Stargaze towards Sagittarius and you're looking at the densest, richest part of our galaxy (Fig. 7.5) where

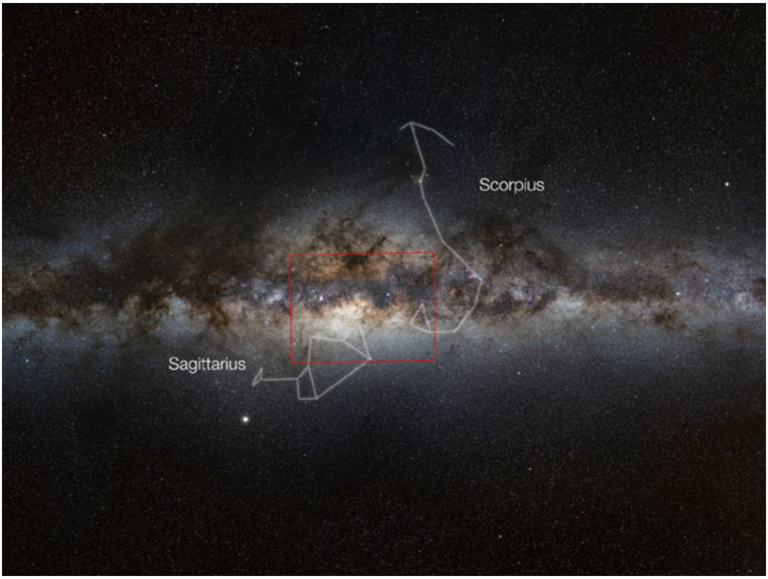

Fig. 7.5 Scorpius and Sagittarius lay across the center of the Milky Way where the night sky is busiest. Credit: ESO/Serge Brunier

star clusters and star-forming nebula are abundant. Find a comfy place to sit because a few hours spent staring at this region with a pair of binoculars doesn't even begin to do it justice. These few targets serve only as brief highlights in this, the busiest yet most fleeting region of the night sky for stargazers in mid-northern latitudes.

Naked Eye Constellation: Scorpius

You've already found the chief star of Scorpius, Antares (see above), which lies below the constellation of Ophiuchus (Chap. 6) and between Libra and Sagittarius. Best viewed June through August, to see the unmistakable line of stars that make Scorpius is a treat indeed, though depending on your latitude you may have to head south to see it.

The Tragedy of Latitude

The area of the night sky around Scorpius and Sagittarius is busy with stars, though both are hard to see from the northern hemisphere. If you're stargazing from about 40° north or higher, Scorpius and Sagittarius are challenging even to glimpse. Perhaps it's time for a trip nearer to the equator (Chap. 13).

Binocular Asterism: The Teapot

Its rather convoluted parent constellation Sagittarius might be tricky to piece together, but it's this asterism that you need to focus your search on. It's best viewed late at night this month, and slightly earlier next, though you will need a clear southern horizon. While the lower stars in Sagittarius are probably hidden, it should be possible to find the Teapot shape (Fig. 7.6). The part of the sky just above the Teapot's spout is crowded with stars, open clusters and nebula. This steam of the Teapot is the Large Sagittarius Star Cloud, the central bulge of the Milky Way some 30,000 light years distant (De Laet 2012). It's a region of sky that's made many a stargazer hot under the collar.

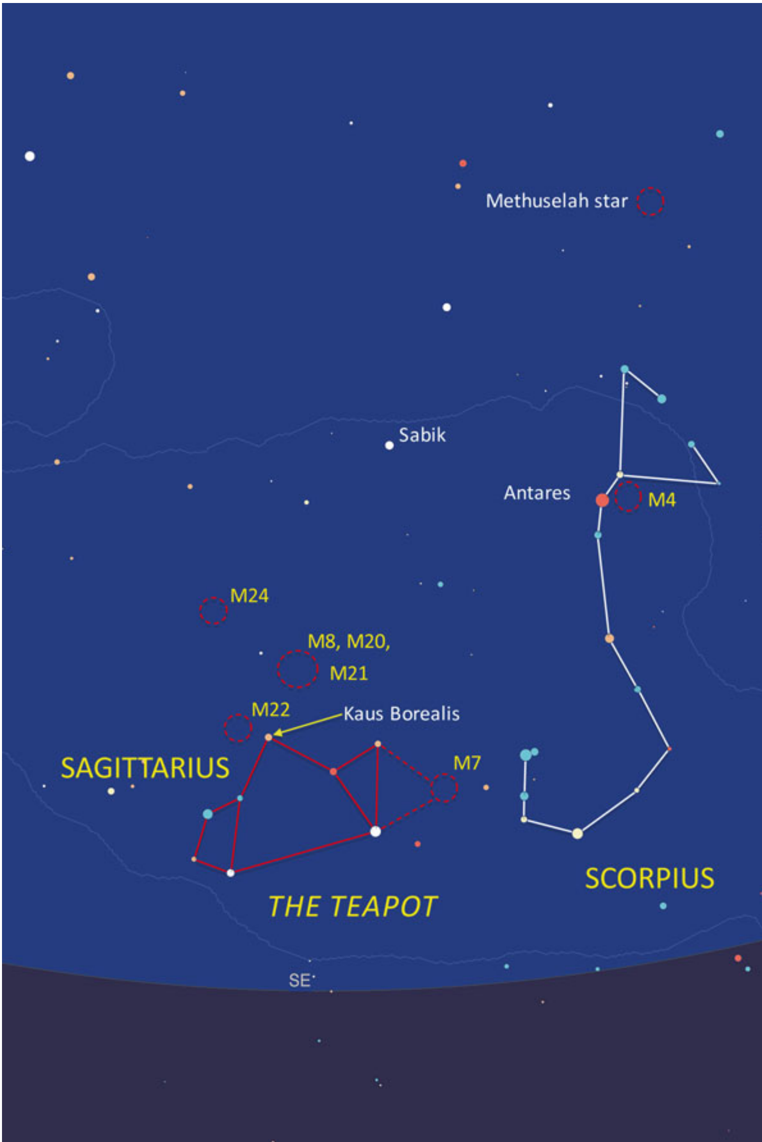

Fig. 7.6 Around the Teapot asterism in Sagittarius are many stars, open clusters and nebula

Binocular Target: Ptolemy's Cluster, M7

The third brightest Messier object after the Pleiades and the Beehive, this loose star cluster is best seen with binoculars, which should pick out about 15 stars, though there are around 750 here (De Laet 2012). Find it by making a triangle from the Teapot's spout; it's also about halfway towards the sting in the tail of Scorpius (Fig. 7.6). Around 1000 light years distant, Ptolemy's Cluster lies over the inner spiral arms of the Milky Way, though still in the Orion Spur.

Binocular Target: Globular Cluster M22

At just 10,000 light years distant, M22 is the closest globular cluster to us, and can be easily seen since it's near the ecliptic. You can find its light—the light of half a million stars—by aiming binoculars at the star Kaus Borealis (Fig. 7.6) at the top of the lid of the Teapot, then looking to the left of the field of view. It's also the brightest globular cluster visible in the northern hemisphere (only 47 Tucane and Omega Centauri, both in the southern hemisphere, are brighter, Chap. 13), though M22 is fleeting compared to the summer-long visibility of the Great Hercules Cluster (Chap. 4).

Binocular Target: Lagoon and Triffid Nebulae, M8 and M20

Seen the Orion Nebula? If you can see Sagittarius, have a look at the 'other' glowing, star-forming nebula in the northern sky, which is similar, but much further away and fainter. While the Orion Nebula—almost directly the other side of the solar system in the Milky Way—is 1,270 light years distant, the Lagoon Nebula is more than three times further from us. Find it above the spout of the Teapot; start at the bottom of the spout and travel to the top, then go the same distance again (Fig. 7.6). Just above is the Triffid Nebula, M20, a bright hazy patch in binoculars; this is also a star-forming region. In the same field of view is M21, a cluster of around 70 stars. Come back to this region of sky next month or next year if you decide to get a telescope—it's fabulous in any optics.

Binocular Target: The Small Sagittarius Star Cloud, M24

Much of the core of the Milky Way is blocked by dust and interstellar matter, but in one of the gaps is M24, the Small Sagittarius Star Cloud. Situated directly above the lid of the Teapot, it's so dense with stars that binoculars will only show a fuzzy patch. M24 isn't an open cluster, but instead offers a star-studded tunnel through to the Norma Spiral Arm that wraps around our galaxy's center. The stars in M24 are at least 12,000 light years distant.

Binocular Target: The Methuselah Star

How can a star be older than the Universe? That's impossible, yet the Methuselah star—the oldest star ever discovered—is officially 14.5 billion years old despite the Universe itself being a mere 13.8 billion years old. Just 190 light years away from Earth in the constellation of Libra (range up from Antares in Scorpius, though at magnitude +7 it's faint), the Methuselah star was aged by the Hubble Space Telescope, but crucially with an error rate of 0.8 billion years. That puts it just after the Big Bang. Known about for more than a century because of its fast motion across the sky, the Methuselah star (officially called HD 140283) is a brief visitor to the Milky Way. It comes from a group of ancient stars that encircle the Milky Way, and was probably born in a primeval dwarf galaxy that was eventually consumed by a growing Milky Way 12 billion years ago (NASA 2013). It's on its way back to the galactic halo to join the other old-timers out there.

Swapping Hemispheres

For the clearest views of Scorpius, Sagittarius and the Milky Way as well as nearby galaxies, brighter globular clusters and nebulas, you'll have to head south of the equator and get to grips with the southern hemisphere night sky. This upside-down journey south can be disorienting as familiar constellations confuse amid a plethora of new and baffling stars, while the Moon appears upside down. Every stargazer should head south to observe at least once if they can (Chap. 13).

The Inner Planets

It's only when the Sun dips below the horizon, or is about to rise, that you can sometimes spot the inner planets Mercury and/or Venus. They're often called the inferior planets because of their position closer to the Sun than Earth. Understanding the rough positioning and movements of these planets in the night sky is key to watching the solar system in action.

The Brightest 'Star'

If you see a bright star above the horizon in the west just around sunset, it's almost definitely Venus. Venus is the brightest object you can see in the night sky after the Sun and the Moon, but unlike either, you'll never see it at midnight. When Venus is furthest from the Sun—something astronomers call maximum elongation—it can hang around in the early twilight for some hours before it sets. It's brightness, and its appearance very low on the horizon is why Venus is said to be responsible for the majority of UFO sightings.

When Venus is bright and so easy to catch before dark, people often notice it, very often for the first time, and wonder what it is. It looks unfeasibly, almost impossibly bright. It looks like an interloper.

Stargazers know better. The paths of the planets around the Sun have been studied, plotted and predicted thousands and thousands of years into the future. Just as an Earth year has various waypoints, such as the solstices and the equinoxes that mark the changing seasons, so do the planets. However, because a year simply measures the length of an orbit of the Sun, no other planet has a year like ours. Highly predictable though they are, the movements and positions of the planets seems to us, on Earth, to be unpredictable and random.

The Impetuous Planets

There is no rule for when to see the inner planets precisely because we're one of them. A year—one orbit of the Sun—on Mercury and Venus last just 88 and 225 Earth-days, respectively. With Earth also moving fast around

the Sun, these two planets appear to ping back and forth fast, popping in and out of the Sun's glare, often being visible at sunset for weeks (Mercury) or months (Venus) on end, before disappearing for long periods. Mercury is smaller even than Jupiter's moon Ganymede (Chap. 4), and it's orbit is so close to the Sun that we rarely see it; unless they're behind the Sun, Mercury and Venus are always in our sky, but are so near to the Sun that they're made invisible by daylight.

The Outer Planets

For a slow-moving planet, like super-bright Jupiter (which takes almost 13 Earth-years to orbit the Sun), you might think that it should be visible every night. In any given year it might move from, say, Gemini into Virgo, but not much further. However, even if a planet isn't moving that fast, Earth is, so our viewpoint constantly changes. Earth is whizzing around the Sun every 365 days, so even Jupiter will, from our perspective, rise and set at different times throughout the year and disappear from the night sky for a few months each year. Why? The Sun gets in the way.

From Dusk till Dawn

All planets appear to move along the ecliptic from east to west, slowly getting closer to the Sun. From being visible just after sunset, they drop into its glare, only to emerge as pre-dawn objects some weeks later. This can be hard to get your head around; how can something be visible before sunset, then just a few weeks later be visible just before dawn? It sounds like time-travel. Again, it's merely a perspective issue; instead of interpreting the night sky from Earth's surface, it can be useful to take a mental step-back and imagine that you're standing behind our planet, and looking at the solar system as a whole. As the Sun gradually moves through the zodiac constellations along the ecliptic (Chap. 6) each year, the outer planets move across the night sky until they become invisible in the Sun's glare. With Earth and Jupiter on opposite sides of the Sun, both are invisible to each other, but as Earth moves further around the Sun, Jupiter will become visible in the morning pre-dawn sky, rising just before the Sun.

Planets Go Backwards

Though they appear to drift from east to west across the night sky, the planets orbit the Sun in the opposite direction along the ecliptic. From Earth we don't get to witness complete orbits of planets precisely because we're on a journey around the Sun ourselves. Consequently, the circuit of a planet passing through our night sky has an odd feature; all of the planets occasionally appear to go backwards. It can happen to a planet for weeks on end, something called retrograde motion by astronomers.

Why is this? Precisely because the planets are going around the Sun and that—crucially—we are too, our line of sight to them changes. Since all planets orbit at different rates, Earth is constantly catching them up and overtaking them as it hurtles around its relatively small orbital path. Consequently, their orbital speeds appear to speed-up and slowdown, and they appear to go backwards, before returning to their normal trajectory. A car traveling at 80 mph will appear to go backwards when viewed through the window of a passing car going at 90 mph. You get the idea.

The Geocentric Illusion

It may seem an interesting anomaly, but it's only retrograde motion that shows us that planets are going around the Sun, and not around Earth. Not big news to us, but an epoch-defining realization just a few hundred years ago.

Believing in the geocentric model—where everything in the night sky orbits Earth—is an understandable mistake. To the casual stargazer, the evidence is everywhere; the Sun, the stars and the planets all appear to move through our sky. But what convinced Nicolaus Copernicus in the sixteenth century, and eventually all humanity, that the Sun was at the center, wasn't just the planets' retrograde motion. He noticed that Venus has phases.

The Evening Star

The second planet is a special sight for stargazers. It's not always visible (check on an app or astronomical calendar), but when it is, don't miss Venus. At a magnitude of between –3.8 and –5 it's much brighter than Sirius (Chap. 1). It's most often seen in the evening in the hours after a sunset, hence the 'Evening Star' name, though it's just as often a super-bright object just before dawn.

Binocular Target: Venus

As well as good timing, you'll need a reasonably low horizon to the southwest to spot Venus. Its apparent magnitude and size can double; at its brightest and biggest it's a whopping –5, so an easy binocular target. When it's at maximum elongation (the furthest it gets from the Sun, from our point of view on Earth) it's half-lit—much like the Moon at First Quarter—and shrinks down to a crescent as it appears to get closer to the Sun, and thus lower in the western sky just after sunset. Though it's possible to see the phases in binoculars, too, it's much easier in a telescope, so don't forget to come back and look at Venus next time it is up.

Committed Venus-watchers should know that it has an eight-year cycle (in which it orbits the Sun 13 times (Espenak 2012), with one year of that cycle spent dominating first as a brilliant Evening Star, and then as a Morning Star. It's then possible to both see it at midnight for a short period, and watch its phases carefully (Fig. 7.7). The next 'Year of Venus' is in 2023.

The Elusive Planet

Mercury orbits very close to the Sun, so it's always up there in the daytime sky, but that makes it impossible to see most of the time. Mercury's orbit is so fast that this hot rock is only visible for about 20 days each year in the northern hemisphere (McCann 1999).

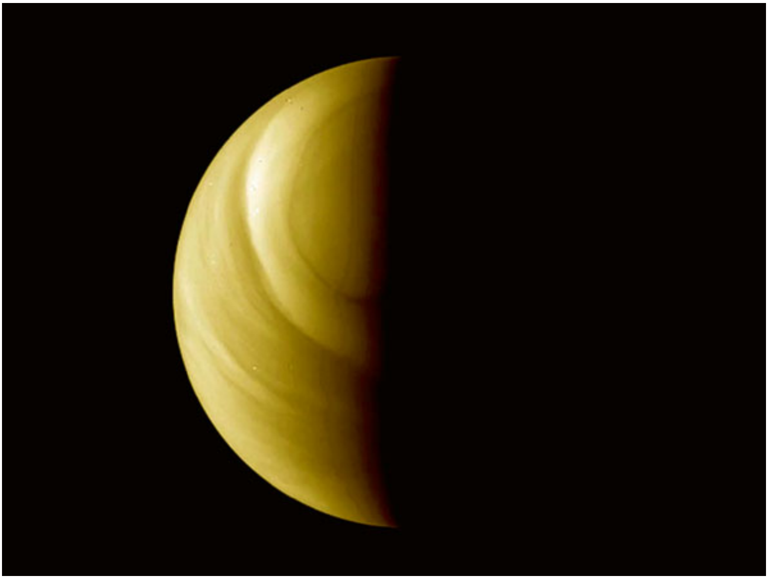

Fig. 7.7 From Earth, Venus appears to have phases; when it appears furthest from the Sun, it's half-lit, reducing to a crescent as it gets closer. Credit: ESA/MPS/DLR/IDA, M. Pérez-Ayúcar & C. Wilson

Binocular Target: Mercury

To have a chance of seeing Mercury, you need to have a clear view to a low western horizon, and be outside about 20 minutes after sunset. In the southwest sky you should be able to see a glow from the Sun, and a tiny yellow light that will brighten as that glow recedes. The clock has then started ticking on Mercury, which will have sunk perhaps within minutes and certainly within an hour or so. Blink and you'll miss it, but Mercury in binoculars is still a fine sight and an excellent way to kickstart some stargazing.

Mercury can be as bright as –1.9, but you may find that it is elusive even when it's supposed to be visible, so go looking for clear skies and a low western horizon. An easier way to see Mercury is to get above the clouds (Chap. 12), from where you'll see Mercury turn visibly orange as it enters the horizon's haze, much like the Sun does as its sinks.

Naked Eye Target: Venus and Mercury in Conjunction

Unless you consult an app, planetarium software or an astronomical calendar, finding Mercury is usually done by accident. If you're being treated to a bright Venus on clear nights—something that can last weeks or months—at some point you may see Mercury close by. To witness Venus and Mercury together is a special treat (Fig. 7.8).

Delta Aquarids

Late July sees the peak of the Delta Aquarids. Meteor showers come and go—and many disappoint or are blocked by bad weather—but any chance of shooting stars in summer shouldn't be overlooked. This is the season to be outside stargazing late at night, and that's most easily done if you're camping. If that's your idea of fun, plan to camp during the Delta Aquarids, which peak at the end of this month and can produce 15–20 meteors per hour.

Fig. 7.8 Venus & Mercury in conjunction just after sunset. © Jamie Carter

The Northern Cross

We've had the Winter Circle, the Winter Triangle (Chap. 2) and the Summer Triangle (Chap. 6), and we'll look at the Southern Cross later (Chap. 13), but now it's time for another seasonal staple, the Northern Cross. This one is actually already familiar to you, being part of, and wholly within, the Summer Triangle, but it's a famous asterism in its own right.

Naked Eye Asterism and Constellation: The Northern Cross and Cygnus

The Northern Cross is the constellation of Cygnus the swan, but backwards. The base of the cross is marked by Albireo and the top by Deneb (Fig. 7.9). Since it also sits across the Milky Way, the Northern Cross is useful for stargazing when you're in a dark sky site. It's X marks the spot, with the cross both covering and pointing in the same direction as the Milky Way.

The asterism also marks the Galactic equator, yet another line in the sky that marks the plane of the Milky Way. If you're under a really dark sky, just below a line from Sadir to Albireo is the Great Rift (Fig. 7.9), a dust cloud between the solar system and the Sagittarius Arm of the Milky Way (Chap. 8). It's visible as a dark band within the bright band of the Mliky Way.

Meanwhile, the constellation of Cygnus has Albireo as the bird's head, with its wings spread further back, either side of Deneb.

Splitting Stars

To split stars is to make-out two or more separate stars where there appears to be—with the naked eye—just one star. We've previously split Mizar and Alcor in the Big Dipper and Epsilon Lyrae in Lyra by looking first with the naked eye then again with binoculars (Chaps. 1 and 4). It's something we can do right across the sky; there are multiple stars that aren't alone. Some are just two unrelated line of sight stars that appear to be next to each other, while others are true binary star systems. While the former are an optical illusion, the latter are gravitationally bound; they orbit each other.

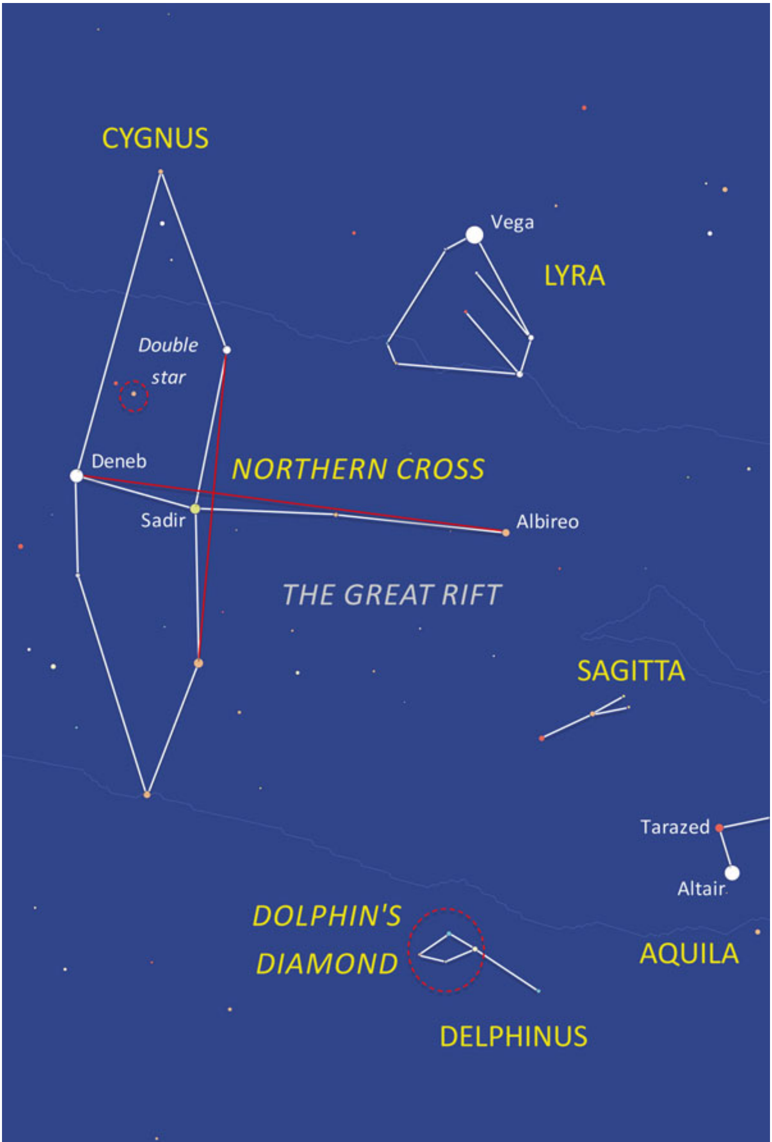

Fig. 7.9 The Northern Cross within Cygnus, a double star near Deneb and the tiny constellation of Delphinus

Naked Eye and Binocular Target: Omnicron 1 Cygni and Omicron 2 Cygni

Just under halfway between Deneb and the tip of the swan's uppermost wing you'll see a double star that's easy to split with the naked eye (Fig. 7.9). Try it with binoculars and you'll see the orange color of both stars. This is a line of sight double; Omnicron 1 Cygni is about 880 light years distant, with Omicron 2 Cygni around 400 light years further away. We'll return to these two in October to find even more stars here (Chap. 10).

Naked Eye Constellation: Aquila

Rising in the east this month is the constellation of Aquila, which has Altair—the most southerly point of the Summer Triangle—as its brightest star. Visible until October, this constellation straddles the Milky Way slightly further south than the Northern Cross (see above). However, there's little to see here with the naked eye aside from Altair, which lies a mere 16 light years distant, and Tarazed, the star just above, which is 460 light years distant (Fig 7.9).

Binocular Constellation and Asterism: Delphinus and the Dolphin's Diamond

This wet constellation (Chap. 10) has no bright stars and is extremely small, which may not sound very enticing, but it's perfect for binoculars. Rising in the east and just to the left of Aquila this month, Delphinus—which is purely a line-of-sight constellation—is centered upon the Dolphin's Diamond asterism within it, a diamond-shape made by four stars around magnitude +3 (Fig. 7.9). The closest star to us in Delphinus is the brightest, Rotanev, at 100 light years.

Once you've found Delphinus, you'll see it time and again if you gaze anywhere around the Summer Triangle. Though it's a good constellation to get to know now, Delphinus is actually at its best in September and October. Five exoplanets have been found around the stars of Delphinus (PHL 2014).

Moon-Shades and Lunar Seas

The long nights of summer are a great time for Moon-watching as you wait for true darkness to open-up the night sky. However logical it might sound to wait until Full Moon so the entire sphere is visible, by then the surface is too bright to look at. Try to catch the Moon around First Quarter. Saying that, there is an easy way of looking at a Full Moon without the glare; wear a pair of shades. It's lunar sea lunacy, for sure, but Moon-shades can help you whether you're Moon-gazing with the naked eye, binoculars and even a telescope.

Naked Eye and Binocular Target: The Moon's Lunar Seas

The most striking thing about the surface of the Moon is the dominance of dark grey patches in the north, and the southern hemisphere's much lighter grey color. These lunar maria—Latin for seas—are solidified lava plains formed by volcanic eruptions in the distant past. There are many to choose from, though the most pronounced are the Sea of Serenity, the Sea of Tranquility and the Sea of Fertility lined-up in the northeast of the Moon (Fig. 7.10).

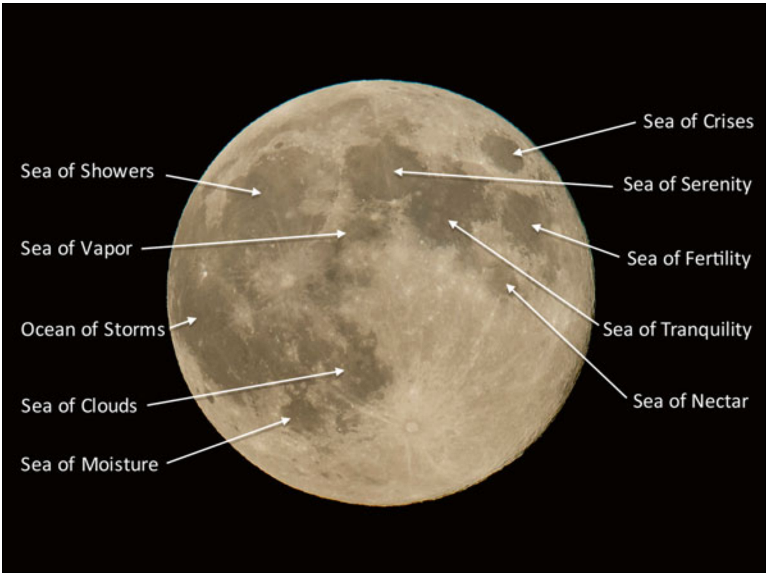

Fig. 7.10 The Moon's major lava seas. Credit: NASA/Bill Ingalls

References

Bobrick, Benson. The Fated Sky: Astrology in History. Simon and Schuster, New York. 2006.

De Laet, Rony. The Casual Sky Observer's Guide: Stargazing with Binoculars and Small Telescopes. Springer, New York, Dordrecht, Heidelberg & London. 2012.

Espenak, Fred/NASA/GSFC. Six Millennium catalog of Venus transits: 2000 BCE to 4000 CE. [ONLINE] Available at: http://eclipse.gsfc.nasa.gov/transit/catalog/VenusCatalog.html [Accessed 01 June 15]. 2012.

McCann, David. Mercury's orbit and phases. [ONLINE] Available at: http://www.skyscript.co.uk [Accessed 01 June 15]. 1999.

NASA News Release Number STScI-2003-19: Oldest Known Planet Identified. [ONLINE] Available at: http://hubblesite.org [Accessed 02 June 15]. 2003.

NASA News Release Number: STScI-2013-08: Hubble Finds Birth Certificate of Oldest Known Star. [ONLINE] Available at: http://hubblesite.org. [Accessed 05 June 15]. 2013.

The Planetary Habitability Laboratory (PHL), University of Puerto Rico at Arecibo. The Constellations of Exoplanets. [ONLINE] Available at: http://phl.upr.edu [Accessed 02 June 15]. 2014.

Sessions, Larry. Antares is Heart of the Scorpion. [ONLINE] Available at: http://earthsky.org [Accessed 02 June 15]. 2014.

CHAPTER 8

AUGUST: THE MOON, METEORS AND THE MILKY WAY

The Stars of August

We're approaching stargazing nirvana this month, with the nights drawing in and temperatures warm enough for long, lazy looks at the cosmos. It's an ideal time to camp, not just because of the kind environment, but also the appearance of another meteor shower. This time, it's serious; the Perseids is an annual highlight of the stargazing calendar, and can rain down up to 100 meteors per hour, sometimes more. If the Moon is out of the way it can be a stunning experience. Choose a dark sky sight and you could be in for one the highlights of your stargazing career.

A Full Moon sure can ruin observing sessions, but don't forget that its initial rising as a softly-lit orange disc is a hugely under-appreciated spectacle. The Summer Triangle continues to be impossible to ignore after dark, while the warm nights make August the perfect time to try your hand at star-trail photography. It's a simple technique, and the patterns you can produce will give you a new perspective on the rhythms of the night sky. So too will learning about the lives of stars, and the mysterious outer solar system (Fig. 8.1).

The Magic of a Moonrise

The Full Moon is best avoided. While that's good advice for stargazers after ultimate night sky clarity, it doesn't account for one simple fact; most stargazers love the Moon, even when it is bright and ruinous to the rest of the night sky.

The sight of Full Moon peeking above the horizon and turning from deep orange (Fig. 8.2) to a pale yellow to a bright, shining white disc while

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_8

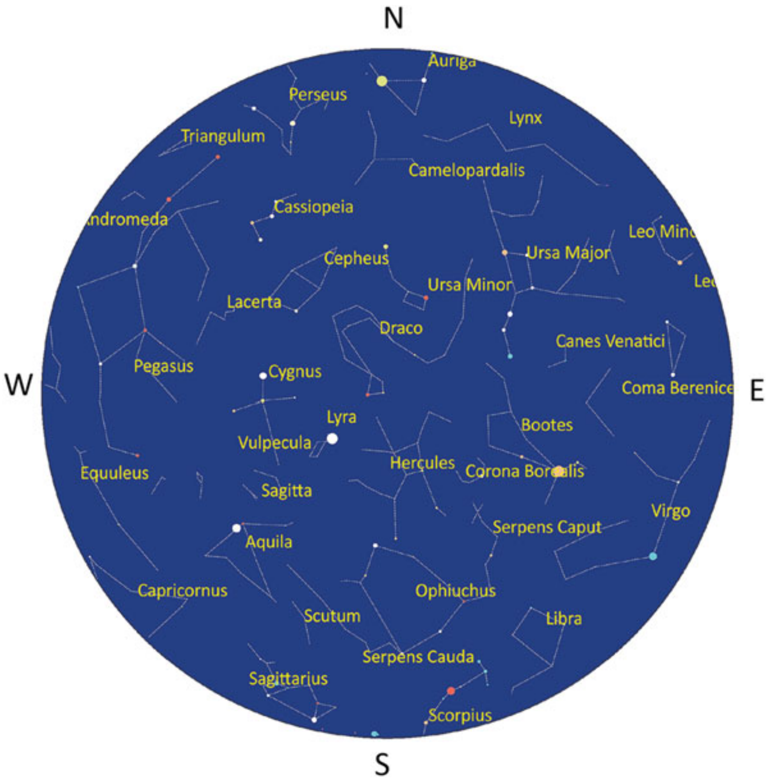

Fig. 8.1 Star-chart for August 1 at 10 p.m.

twilight fades is a spectacular sight. Though almost everybody on Earth is too busy to view it, it's a must-see for stargazers each month, though it does require impeccable timing. Think of it as a reward; a waxing First Quarter Moon the previous week will have made stargazing near impossible.

Predicting the Moonrise

Like everything else in the night sky, a rising Full Moon is predictable down to the second. Simply find out on what date the next Full Moon is going to be (it's probably already printed in your diary) and exactly what time

Fig. 8.2 A Full Moonrise is one of stargazing's most awesome sights. Credit: NASA/Bill Ingalls

sunset is on that date, then look to the east in the opposite direction to where the Sun is setting.

The colorful spectacle lasts mere minute and is easy to miss. If you've ever seen photos of someone silhouetted against a seemingly giant Moon, perhaps while standing on top of a hill, they were taken in these brief moments, so were likely no accident. To make the Moon look so large in the background photographers use super-zoom lenses of around 400 mm while positioned a mile or more away. For the rest of us, a pair of binoculars reveals a memorable sight each month (Fig. 8.2).

If you miss the Full Moon rising (probably because of a cloudy horizon) either wait for the equally beautiful Moonset at dawn, or look again the next night about 50 minutes after last night's Moonrise. Missed it again? Wait a further 50 minutes, though by then the Moon will be on the wane and rising in darkness, so the chance to see Moon-glow and color on nearby clouds is lessened.

The Full Moonrise is also a watershed for stargazing. Since it's about to disappear from the early evening skies completely for a few weeks, this is the best time to head for your nearest truly dark sky (Chap. 15) for uninterrupted stargazing.

Binocular Target: The Full Moonrise

Can there be a better sight than the Full Moon, glowing orange, rising between chimney stacks, trees or mountains? Timing is everything here; you must be in as high a place as possible at the exact time of Moonrise on the day of the Full Moon, which is almost exactly the same time as Sunset. Get in place with binoculars around your neck and wait a few minutes. The advantage of watching at this exact time is that it will appear to look very large and move very quickly, lending a real sense of drama. Keep those binoculars fixed upon it and you might spot an airplane or a flock of birds appear to cross the Moon. Such an event, beloved of photographers, is a common sight for Moon-watchers.

Twenty minutes after rising, the Moon is up, it's yellow-white, and it's too bright to look at for long. If there is some cloud on the horizon (there often is) it can actually improve the spectacle by suppressing a little of the brightness and giving the surrounding clouds a beautiful Moon-glow.

What Is a Super Moon?

A lazy term often used by the media, a Super Moon is merely when our satellite is the nearest it gets to Earth in its orbit. It doesn't necessarily coincide with a Full Moon. Since the Moon orbits in a slightly titled, elliptical orbit, there are always going to be points when it appears slightly smaller when it's the farthest away (known as the Moon's apogee), or slightly bigger than when it's at its nearest point (called its perigee). The difference is about 25,000 miles, or about 10 % of the average distance between the Earth and the Moon. A Full Moon at apogee won't appear as bright or as big as a Full Moon at perigee, which is generally what's known as a Super Moon (Fig. 8.3). Down on Earth, slightly stronger high tides are the result, but from a Moon-watching perspective, it's the Super Full Moon that's the masterpiece; it can look particularly large as it rises above the horizon at sunset.

Super Moons often cause confusion. At a solar eclipse in 2015 dubbed a Super Moon Eclipse by the media there were people genuinely expecting

Fig. 8.3 A Super Moon can only be seen when the Moon is both at its closest to Earth and in the Full Moon phase. Credit: NASA/Bill Ingalls

to watch the large New Moon pass in front of the Sun in the morning followed by an overly large Super Full Moon at sunset. Think about the Moon's orbit and you'll quickly realize that would be impossible.

A Fireball Festival

If there's one date range that should be in every stargazer's diary, it's August 9–13, the dates of the Perseids meteor shower (Fig. 8.4). It's the most prolific of the year. Deemed the Tears of St. Lawrence by Catholicism because of its timing near a saint's day, the Perseids are the result of Earth's orbit of the Sun hurtling through a stack of debris left over from a comet called Comet Swift-Tuttle, which passed through the solar system most recently in 1992 on its 133-year orbit of the Sun.

The Perseids offer about 50–100 or more meteors per hour. Treat a meteor shower like wildlife-spotting; the more you look, the more you see.

Fig. 8.4 The Perseids meteor shower is caused by Earth speeding through a stream of debris left by Comet Swift-Tuttle. Credit: ESO/S. Guisard

The spectacle of seeing three bright meteors streak across the sky inside a few seconds is price-less but demands patience, so avoid the temptation to check your mobile phone or do anything else that takes your gaze from the skies.

Naked Eye Target: The Perseids Meteor Shower

By now you'll have seen plenty of shooting stars just from regular stargazing, but the Perseids are special. We're talking big, bright, sparkling fireballs that often appear to leave a trail behind them. Instead of a fraction of a second, each shooting star can last a full second. If the conditions are right, it can be an unforgettable experience.

The exact dates change every year, though the deciding factor is, as always, the position of the Moon. If it's a Full Moon or close, there's a big chance that all but the bright meteors will be obscured, though it needn't be a washout. If a really bright Moon is casting shadows and really interrupting your view of the sky, one trick is to get into the shadow of a building or mountain. With less ambient light, the meteors should be appear brighter. You should observe between between midnight and 2 a.m., when the night sky is darkest. The Perseids offer more fireballs than any other shower, so if there are clear skies, keep looking.

As Earth busts through the biggest part of the comet debris, the Perseids peak for 24 hours, though it's worth looking for meteors a few days before and after. It's better to go for a clear sky and fewer meteors a few days before the predicted peak than planning a trip to a dark sky site on the big night if bad weather is predicted.

The constellation of Perseus, just below Cassiopeia, is the radiant of the shower, the point where the meteors appear to stem from. Fix your gaze on this patch of sky, and above, but don't get dogmatic about it; a meteor might just as easily start above your head and whizz south. However, to look low to the southern horizon would be a mistake.

Shooting star-gazing is best done while laying down on the ground. The weather means it's rarely possible to do that, but there's less excuse in the warmer, drier temperatures of August.

Zodiacal Light

Light pollution can be beautiful. Although it's possible to visualize exactly where the plane of the solar system is just by looking at the planets and tracing the line of the ecliptic across the sky, it is also possible to see the solar system glow. Called zodiacal light, faint columns of brightness (Fig. 8.5) can be seen in the west after dusk in spring and in the east before dawn during fall, though you will need low horizons.

These are caused by the Sun's light hitting dust particles in the solar system and scattering across the plane. Zodiacal light is sometimes mistaken for light pollution, though you'll only see it if you're far from towns and under Moon-less skies.

Fig. 8.5 Zodiacal light can sometimes be seen just after twilight. Credit: ESO/Y.Beletsky

Triangle Targets

By now the celestial trio of Altair, Deneb and Vega will have become very familiar, but there's yet more to find within the Summer Triangle including an elusive space between the stars.

Naked Eye Target: The Sagittarius Arm of the Milky Way

The Summer Triangle (Chap. 7) is in front of a particularly busy part of the Milky Way. It passes behind Deneb and down behind Altair before dipping below the south-west horizon.

The best way to both see and appreciate the Milky Way is to stay outside for 30 minutes, and by lying on the ground. It's perhaps best done this month while waiting for Perseids meteors.

Binocular Target: North American Nebula, NGC 7000

You'll need a dark sky site to see this one, but wherever you look from, there's nothing to see. Gaze at the patch of sky just to the left of Deneb and you might be able to make-out this space between the stars; it's about three times the size of the Moon and is said to resemble the shape of North America. It's easily visible in 10× binoculars.

So why no stars? Actually there are stars, but we can't see them because of this nebula, a huge cloud of interstellar dust that blocks and distorts the starlight behind it. The spaces between the stars can tell us much about the night sky, and some cultures have developed constellations based around these dark patches[1] (Chap. 13).

---

[1] Such as the Inca in Peru, and Aboriginal Australians.

Hanging on a Star

Nestled within the Summer Triangle, the beautiful Coat-hanger asterism is summer's answer to the Pleiades. One of the few objects in the night sky whose name is accurately descriptive rather than just fanciful and imaginative, nine blue stars and one orange star trace-out the surprisingly well defined shape of a Coat-hanger, though it's upside-down to us in the northern hemisphere.

Binocular Target: The Coat-Hanger Cluster

The Coat-hanger can be found about mid-way between bright star Altair at the foot of the Summer Triangle, and Albireo in the middle (Fig. 8.6). It's easily visible even in light-polluted skies. The orange star is HR 7391, a giant star 610 light years distant. The Coat-hanger is also known as Brocchi's Cluster and Collinder 399.

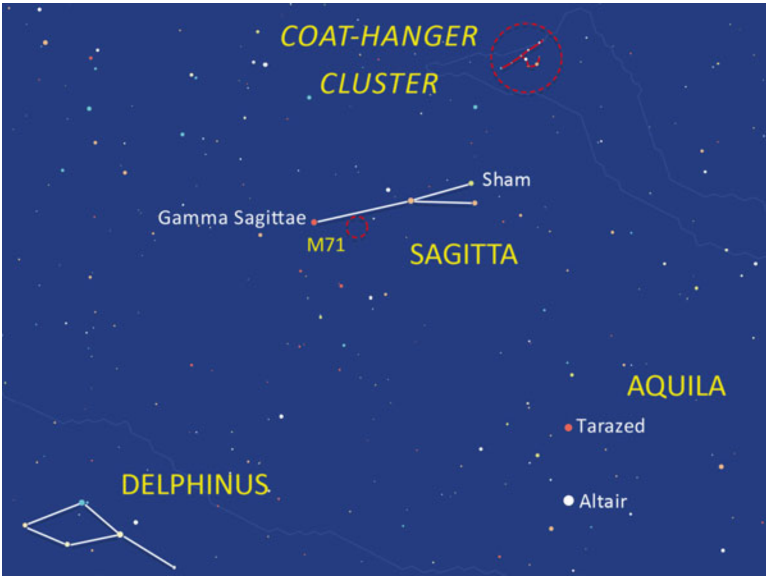

Fig. 8.6 Within the Summer Triangle is globular cluster M71, the tiny constellation of Sagitta, and the Coat-hanger Cluster

Binocular Constellation: Sagitta

Range down and slightly left from the Coat-hanger (Fig. 8.6) and you'll reach one of the smallest constellations in the sky. Comprised of only four easily seen bright stars, Sagitta is shaped like an arrow, pointing east. There are two stars at the tail, one in the center, and a red giant, Gamma Sagittae at the point, which is much the closest to us at around 260 light years.

Binocular Target: Globular Cluster M71

Go back to Sagitta. Half-way between the eastern-most two stars in this four-star constellation (Fig. 8.6) is another excellent globular cluster much like M13, the Great Hercules Cluster (Chap. 4). However, while M13 is a whopping 25,000 light years distant, M71 is only 12,000 light years, and is about nine billion years old. Yes, it's a small fuzzy patch, but return with a telescope in future and you'll begin to see individual stars.

Types of Stars

Stars are not the same. If stars were the same size and brightness, and had identical lifespans, stargazing would be easy. If bright stars were closer and dim stars were further away, we would be able to see the solar system in three dimensions and in real-time without much trouble. The galaxy isn't nearly that simple.

Monsters in our Midst

Stars vary hugely in size and brightness, but as a rule of thumb almost every star you can see is bigger than our Sun. Space is so vast and the stars so spread-out, that we can glimpse only the relatively rare giants and supergiants. Some of the stars we can see may be relatively close to us, but they're not like our Sun. Almost all the stars we've identified so far this year are between several and thousands of times larger than the Sun. Many of them are on the verge of death.

How Stars Work

Most stars you can see in the night sky are both extraordinary and ill-fated. The more massive a star, the shorter its life, and the rarer it is. The smaller a star, the longer it lives, but the more common it is. All stars are nuclear fusion reactors, converting hydrogen into helium, but when they run out of hydrogen, they swell into the giant stars that we can see in the night sky. Betelgeuse, Sirius, Aldebaran, Antares, Capella, Procyon, to name only a few, are exhausting their hydrogen and headed for a supernova explosion. They may end up as a planetary nebula, such as the Ring Nebula (Chap. 5) or as a supernova remnant like the Crab Nebula (Chap. 12) where all that's left is a pulsar or a neutron star, which spin rapidly and give off clockwork-like radio signals. Or they may end up as a black hole.

What all stars have in common is how they're formed, in dust clouds like the Orion Nebula. Over millions or billions of years, stars produce heavy elements and ultimately, in their destruction, spread them throughout the Universe. Cue astronomer Carl Sagan's famous quote: "The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff. (Sagan 2011)."

Categorizing Stars

Stars are also categorized according to their temperature and their mass. From hottest to coolest it goes blue, white, yellow, orange, then red (Chap. 2). Stars are given a letter—or a combination of letters—to describe their temperature and mass, with the seven groups being O, B, A, F, G, K and M, starting at the hottest and ending at the coolest. That's a lot of letters, but know that few stars exist at the extremes.

The Extremes

Massive stars don't live long. O-type and B-type stars are hot, blue giants and supergiants, and though they make up a minuscule percentage of stars, you already know a lot of them. All the stars in Orion's Belt and in the

wider Collinder 70 cluster (Chap. 12), Meissa above, and even the four visible in the Orion Nebula itself, are all either O-type or B-type stars. All are fated to have short lives, and destruct in supernova explosions. So are the equally rare red supergiant stars—known as M-types—which include Betelgeuse, Antares, the Garnet Star and VV Cephei A (Chap. 11).

G Stars: The Sun

So-called yellow dwarf stars—A, F and G-types—make-up the majority of stars in the Milky Way. It's often said that the Sun is a mid-sized, middle aged star, but when compared to most of the stars you can see in the night sky, the Sun is incredibly old. It's classed as a yellow G2 dwarf star, and not even halfway through its 10 billion years-long life.

Though it's nothing special when compared to the whoppers we can easily see in the night sky, the Sun is special both because of that, and because the vast majority of stars are red dwarfs, which are both cooler and smaller (too small to see in the night sky). Since 85 billion of the 100 billion stars in the Milky Way are red dwarfs, stargazers can't see the galaxy for what it really is.

Like all stars that aren't O-type and B-type stars, the Sun—which is bigger than a red dwarf—will eventually run out of fuel, cool and expand to become a red giant, and then shrink to become a faint white dwarf. Though most of the stars we stargaze at are blue or red giants, there are three G-type stars in the northern hemisphere's night sky—specifically in the constellations of Cassiopeia and Pegasus—that are remarkably similar to our Sun, which we'll meet later in the year (Chap. 12).

The Solar Suburbs

While looking at Sagittarius, a constellation on the ecliptic that all of the planets appear to pass through at some point on their orbits, it's a convenient time to learn about the solar system, and consider how little we know about it aside from the major planets.

Mind's Eye Targets: Pluto, New Horizons and Kuiper Belt Objects

Pluto, now relegated to the status of a dwarf planet or Plutoid (Chap. 15), is too small and far away to see with the naked eye. The New Horizons spacecraft spent a decade traveling to Pluto, arriving and photographing it in 2015, before carrying on with its journey to the outer solar system.

Pluto is two-thirds the size of the Moon; you would need at least a 10-inch telescope to even get close to seeing it, but it's not much of a sight. However, it's easy to identify Pluto's general position since its 248-year orbit of the Sun means it doesn't move through the sky quickly; it's just behind the handle of the Teapot in Sagittarius, and will remain close by for many years.

Having photographed Pluto, New Horizons is scheduled to explore the outer solar system, also called the Kuiper Belt, and other so-called Kuiper Belt Objects a billion miles beyond Pluto. We may think we know all about the solar system, but the Kuiper Belt is truly undiscovered country.

The Scale of Space

The bigger the number, the less able most humans are at understanding scale. There's no point in using miles or kilometers, for we can't easily compare vast distances in space to anything any of us have encountered down here on Earth. Astronomers therefore use the astronomical unit (AU), which is the distance between the Earth and Sun. That's 1 AU. It's about 93 million miles, the distance that light from the Sun takes about eight minutes to cover on its way to Earth.

The AU is a useful benchmark when thinking about the solar system. By definition, the inner planets of Mercury and Venus must be less than 1 AU from the Sun, while Mars is only 1.5 AU away. Pluto is a whopping 40 AU distant. Even the AU breaks down when you get beyond the edge of the solar system and reach interstellar space, which is so vast that the light year becomes the only useful unit of measurement.

The Kuiper Belt and the Oort Cloud

The Kuiper Belt is loosely defined as the area of the solar system beyond the orbit of Neptune, which includes Pluto and other dwarf planets such as Eris (which is actually larger than Pluto, hence Pluto's demotion from planet status), Haumea and Makemake (pronounced 'mar-kay mar-kay').

The Kuiper Belt is disc-shaped, and loosely adheres to the plane of the solar system that we can see when we stargaze at planets on the ecliptic (Chap. 3). The Oort Cloud is different. Stretching between 5000 to 100,000 AUs from the Sun, the Oort Cloud is spherical and completely encircles the entire solar system. You can't see the Oort Cloud for its constituent icy bodies (some of them future comets) are far too small, but each time you stargaze you're looking out to, and through the Oort Cloud.

Comets

Rare but often spectacular, comets that reach the inner solar system from either the Kuiper Belt or the Oort Cloud are special targets for stargazers. On a brief trip into the inner solar system to orbit the Sun, a comet often looks like a bright tadpole-like object, usually with one or two tales; they're terrific targets for telescopes and binoculars and, if you're very lucky, just the naked eye. It's notoriously difficult to predict how bright these balls of gas, dust and ice will get even when they do appear, hence Charles Messier's famous non-comet catalogue, which was designed to help his own search for comets (Chap. 4).

Exceptionally bright comets in recent years have included Halley's Comet in 1986 (Fig. 8.7 and Chap. 5), which will return in 2061, and Hale-Bopp in 1997, whose orbit is 2537 years. The former comes from, and returns to, the Kuiper Belt, so is classified as a short-period comet. The latter, from the Oort Cloud, is a long-period comet.

So little is known about comets, the Kuiper Belt and the Oort Cloud that an exceptionally bright comet could appear at any moment. In fact, we'll only know it's here when a stargazer like you or me reports seeing it.

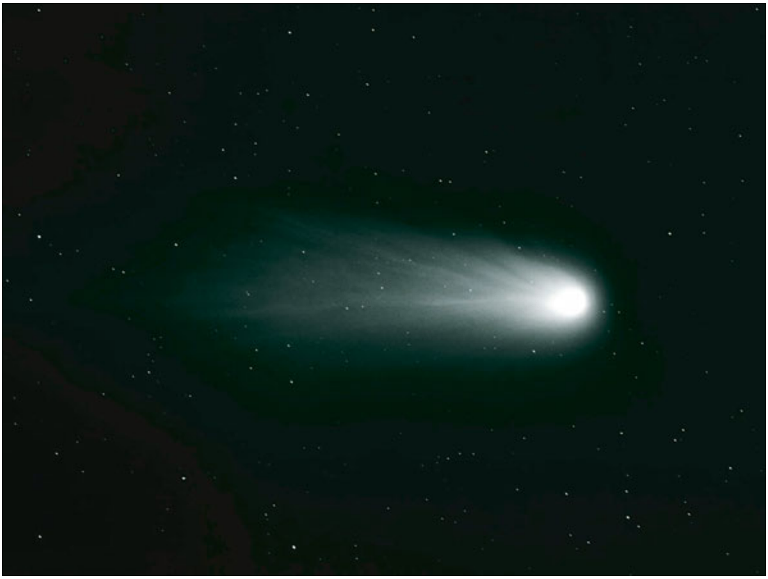

Fig. 8.7 Halley's Comet will return from the Kuiper Belt in 2061. Credit: ESO

Unknown Worlds

Hunting for exoplanets is astronomy's current obsession, with research grants pouring into the search and examination of previously unknown worlds. From giant planets (often called 'hot Jupiters') that orbit their sun in just a few hours to planets in quadruple star systems, what's being discovered is profoundly changing how we look at the Universe, and at our own solar system. Exoplanets are beyond our reach when stargazing, of course, but it's revealing to know where in the night sky astronomers are looking.

Mind's Eye Target: Lyra and Cygnus, Home of the Exoplanets

Here, just above the plane of the Milky Way between Deneb and Vega, is where NASA's Kepler Space Telescope spent four years collecting data on 150,000 stars beyond the solar system. Between May 2009 to April 2013

over 4175 candidate planets were identified within its tight field of view, and over 1800 had been confirmed as exoplanets by 2015. How they're discovered is clever, and has awesome consequences; a star dips in brightness slightly as a planet transits across it, which is enough to allow calculations about the mass of those planets, and the speed of their orbits. Using that technique astronomers can detect planets that orbit in the same plane—i.e. planets that the Kepler Space Telescope has a side-on view of—but no others. Planets that don't transit, from Kepler's limited point of view, can't be detected. There can only be one conclusion. There aren't hundreds, thousands, or even millions of planets in the Milky Way. There are at least 40 billion planets, according to researchers from UC Berkeley and the University of Hawaii extrapolating Kepler's data (Petigura 2013). They're likely in every direction a stargazer looks (Fig. 8.8).

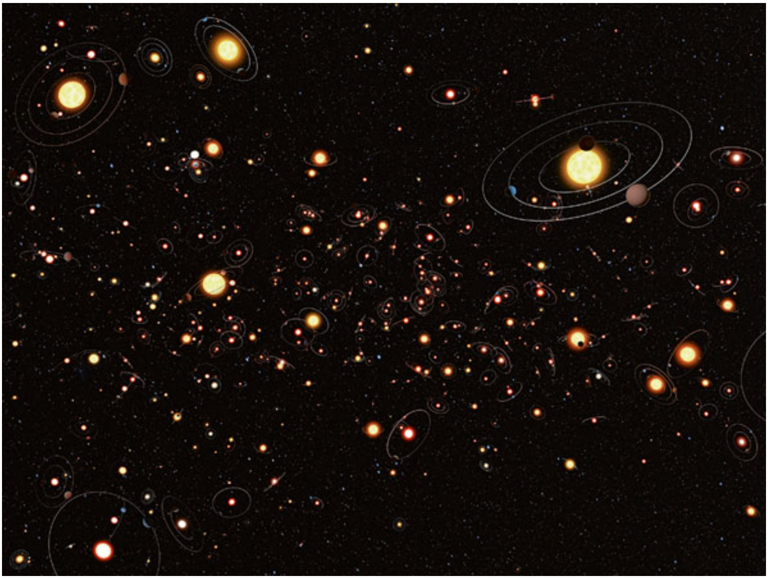

Fig. 8.8 Planets around the stars in the Milky Way appear to be the rule rather than the exception (artist's impression). Credit: ESO/M. Kornmesser

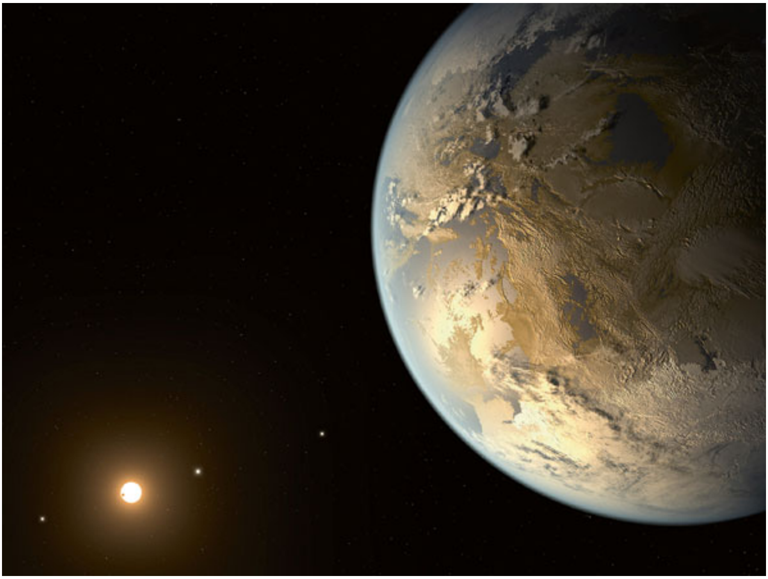

Fig. 8.9 Earth-sized planets have likely formed throughout most of the Universe's 13.8 billion year history (artist's impression). Credit: NASA Ames/ SETI Institute/JPL-Caltech

The Hunt for Earth Twins

Exoplanets may be everywhere, but finding rocky Earth-like planets is much harder (Fig. 8.9). Of the 1000 or so planets found by astronomers, just six are between one to two times the size of Earth and orbit close to a star similar to ours in size and temperature. Warm and possibly wet, this habitable area is sometimes called the Goldilocks Zone. The inference is that similar Earth-like planets might host life. The most Earth-like so far is Kepler-438b, which orbits a red dwarf star called KOI-3284 every 35.2 days (NASA 2015). It's 475 light-years distant, in the constellation of Lyra. In January 2015, a team from University of Birmingham's School of Physics and Astronomy announced that they had found a star, Kepler-444, 11.2 billion years old with five Earth-sized planets orbiting around it. It's the oldest known system of terrestrial-sized planets in our galaxy, and two and a half times older than Earth. Kepler-444 is 117 light years from us in the constellation of Lyra (Campante 2015). It suggests that Earth-sized planets have likely formed throughout most of the Universe's 13.8 billion year his-

tory, which could mean that life is ancient; by the time that the Earth formed, the planets orbiting Kepler-444 were already older than our planet is today.

Photographing Stellar Motion

If you've already attempted a photo of the ISS (Chap. 5) or tried a basic wide-field photo of the night sky (Chap. 6), the next step is to shoot a star-trail. Star-trail photography, especially if it includes a foreground subject (Fig. 8.10), is a great souvenir shot from a trip to a dark sky destination (Chap. 15), but it works almost as well from your own backyard (Fig. 8.11).

There are two ways to produce an image that shows the exact movements of the stars; the first is to open the shutter on your camera for a long period, and the second is to take multiple short exposures and stack them into one time-lapse image using software.

Fig. 8.10 Star-trail over the La Silla Observatory in northern Chile. Credit: Iztok Bončina/ESO

Fig. 8.11 It's possible to produce a rudimentary star-trail even in a light-polluted urban area. © Jamie Carter

Either way, you'll need a DSLR camera on a tripod ideally with a wide-angle lens set to infinity focus, maximum aperture (F3.5 or thereabouts) and ISO 400. To avoid any camera shake, which can easily ruin a star-trail, use a remote shutter or a timer to delay the shutter release by a few seconds.

Infinity Focus

The infinity focus can be a real problem. If you simply line-up the infinity symbol with the focus mark on the lens, you may get blurry stars-trails. That can be a nice effect (Fig. 8.12), but for sharp focus you will need to sort out your focusing beforehand in daylight. Several hours before you plan to shoot a star-trail, pre-focus on a distant object, such as a tree, a mountain or the top of a building using autofocus or manual focus. Once you're happy (take some test shots and check for sharpness), switch to manual focus and either remember where that focus point is, or tape-down the

lens with some masking tape. It may sounds rudimentary, but it works. The same applies for all kinds of astrophotography, including photographing stars (Chap. 6), eclipses and the Northern Lights (Chap. 14).

Where to Point Your Camera

If your camera is pointed at Polaris, you'll get complete star circles, since all stars in the northern hemisphere appear to rotate around it. As circumpolar constellations move around Polaris, you may even be able to identify the blur of well-known stars, such as those in the Big Dipper or Cassiopeia. However, you don't just have to point your camera at the north pole; photos taken pointing the camera to the south will reveal that the stars move in far gentler lines and curves (Fig. 8.12).

Fig. 8.12 Take a star-trail facing south and the stars don't circle, they stretch. This image from Gran Canaria includes the three rather obvious (though defocused) blue stars of Orion's Belt near the top. © Jamie Carter

Option 1: Long Exposure

Set your camera to bulb mode, which allows the shutter to be manually held open. Set your ISO low and leave the shutter open for 5 minutes; you'll get stars that are starting to streak across the sky. If you have really clear skies, try an exposure for 15 or even 30 minutes for an even better effect, but remember that ambient light might ruin it. The advantage of this approach is that it's relatively quick and easy to do, though the finished result can be too bright and noisy, and have very short star-trails.

Option 2: Multiple Exposures

The second approach is to take a series of short exposures and stack them using free software to produce a time-lapse photograph. Expose for 30 seconds as a test shot, and once you're happy with the results, repeat the process (which your camera may be capable of doing automatically) until you have about 100 images, or more if you have the time. Just don't touch the tripod! With free software such as StarStax, you simply drag in the images, wait a few seconds, and a magical star-trail is produced.

References

T. L. Campante and T. Barclay and J. J. Swift and D. Huber and V. Zh. Adibekyan and W. Cochran and C. J. Burke and H. Isaacson and E. V. Quintana and G. R. Davies and V. Silva Aguirre and D. Ragozzine and R. Riddle and C. Baranec and S. Basu and W. J. Chaplin and J. Christensen-Dalsgaard and T. S. Metcalfe and T. R. Bedding and R. Handberg and D. Stello and J. M. Brewer and S. Hekker and C. Karoff and R. Kolbl and N. M. Law and M. Lundkvist and A. Miglio and J. F. Rowe and N. C. Santos and C. Van Laerhoven and T. Arentoft and Y. P. Elsworth and D. A. Fischer and S. D. Kawaler and H. Kjeldsen and M. N. Lund and G. W. Marcy and S. G. Sousa and A. Sozzetti and T. R. White An ancient extrasolar system with five sub-Earth-size planets. The Astrophysical Journal Volume 799 Issue 2. 2015.

NASA. Kepler Discovers 1000th Exoplanet. [ONLINE] Available at: http://science.nasa.gov [Accessed 02 June 15]. 2015.

Petigura, Erik., Howard, Andrew. & Marcy, Geoffrey. Prevalence of Earth-size planets orbiting Sun-like stars Proceedings of the National Academy of Sciences. 2013.

Sagan, Carl. Cosmos: unabridged edition. Random House Publishing Group, USA. 2011.

PART III

DEEP SKY

CHAPTER 9

SEPTEMBER: THE THIRD LAYER

The Stars of September

September is a northern hemisphere stargazer's seventh heaven. Wait for about two hours after sunset for the darkest skies and you'll see the Summer Triangle slowly moving towards the western sky. Towards the end of the month is the autumn equinox, and while there's nothing specific to stargaze at, the Sun's position directly over the Tropic of Capricorn means nights lengthen in the northern hemisphere. That's great news for stargazers, for whom the long, warm evenings make September an ideal time to invest in a telescope and get a close-up of the Moon, planets and a colorful double star. A telescope will give you access to a new, third layer of deep sky, and this month we'll briefly consider the different types of telescopes, and which best suit you.

However, don't forget to cast your eyes towards constellations rising in the east. Learning new constellations remain the easiest way to learn the geo graphy of the night sky, which will become crucial if you decide to buy a telescope.

Some of the stars rising in September will be familiar to you, having been in the south and west back in January and February. In the north-eastern sky, Auriga and its bright star Capella are unmistakable, while alongside it three new constellations rise—Perseus, Andromeda and Pegasus. With warm nights, new sights and a few hundred thousand more stars to immerse yourself in via a telescope, all you need are clear skies. Prepare for a busy month outdoors (Fig. 9.1).

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_9

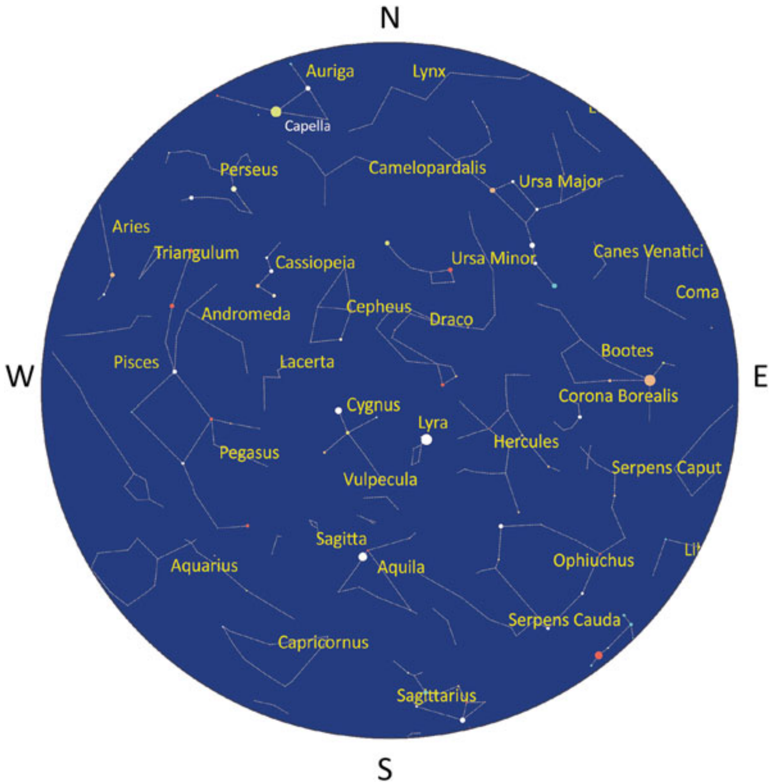

Fig. 9.1 Star-chart for September 1 at 10 p.m.

The Great Square of Pegasus

September sees the rise in the east of one of the signposts of fall, and surely one of the most geometrically precise of all the asterisms in the night sky. Finding the Great Square of Pegasus is a snap since it's marked at each corner by four stars that are roughly similar in brightness (Fig. 9.2).

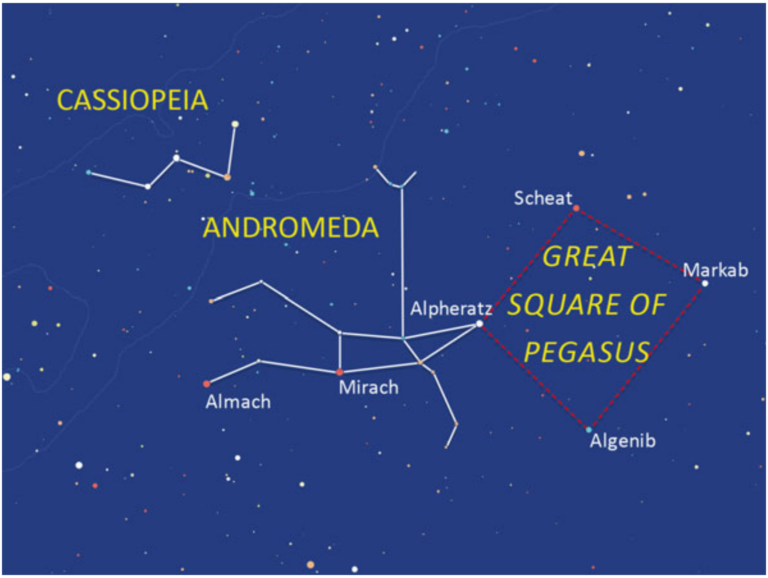

Fig. 9.2 The Great Square of Pegasus rises as a diamond this month, with the constellation of Andromeda beside it

Naked Eye Asterism: The Great Square of Pegasus

You might find it easier to imagine this asterism as the Great Diamond of Pegasus, for it's rising in that orientation this month. At the top is Scheat, flanked by Alperatz (below, left) and Markab (below, right), with Algenib at the bottom, near to the horizon.

The Great Square of Pegasus is the most prominent part of the constellation of Pegasus, which represents the upside-down body of a horse, but the rest of it is hard to see, upside down, and something of a jumble of stars.

It's an asterism often used by stargazers to gauge the darkness of an observing site (and the eyesight of the observer); if you count any more than five stars within the boundaries of the square, you're doing well. From a truly dark sky site you can see around ten. However, one of the stars in this asterism—a corner star, Alperatz—is also in the neighboring constellation of Andromeda.

Naked Eye Constellation: Andromeda

The constellation of Andromeda is meant to look like the figure of a woman whose feet point towards the constellation of Perseus, which is rising in the north-east above Auriga. Alperatz is Andromeda's head, bright Mirach her waist, and Almach her left foot. Look below Andromeda's feet and you may glimpse the Pleiades rising this month, though it will be in the horizon's haze, so far from its best (solution: stay up late!).

Telescopes and the Third Layer

We've so far penetrated the cosmos first with our eyes and, since April, with a pair of binoculars, but a third way of looking at the night sky expands it enormously. With the more powerful optics of a telescope, you'll be able to get close-ups of objects you've already looked at. You'll see planets in all of their glory for the first time, and look deeper into the Milky Way and the Universe beyond.

How deep into the night sky you can see depends wholly on what kind of telescope you've got access to, or purchase, and how powerful its optics are. Even with a small telescope you'll be able to see things that your eyes and binoculars cannot detect. Telescopes are a great way of expanding your horizons as a stargazer, but they do come with caveats.

Why to Buy a Telescope

If used properly, a telescope can blow your horizons wide open. Seeing Saturn's rings for the first time can be a mind-blowing, life-changing moment for any stargazer. Even for those who love the wide-eyed view, it's always nice to have a bit of magnification available.

From eye-balling planets close-up, seeing inside the Moon's craters, splitting stars into colorful doubles, and penetrating star clusters, globular clusters and distant galaxies—mere fuzzy blobs in binoculars—a telescope can really open-up the night sky.

Why Not to Buy a Telescope

For some, a telescope is one step too far. It's where a simple enjoyment of the night sky can veer-off into serious scientific study. Many stargazers don't want to spend hours in the backyard fiddling with a telescope; they want to spend it looking up at the night sky. Who doesn't know someone whose dust-covered telescope from Walmart now stands in a spare room?

Decision Time

If you decide against getting a telescope, simply ignore the telescope targets that are peppered throughout the remaining four chapters of this book. It won't impinge on the rest of your learning since there are as many new naked eye constellations and binocular sights included as in previous chapters.

Taking it Slow

Whatever you decide to do, your eyes and binoculars should, in your first year of stargazing, remain your primary windows on the night sky. Those who decide to buy a telescope in their first year of stargazing should keep it small, learn how to use it properly—and often sparingly—and take things slowly. The cosmos isn't going anywhere.

Magnification and Objective Size

Telescopes are for looking at two types of things in the night sky; faint fuzzy objects, and bright solar system sights such as planets and the Moon. The first requires as much brightness as possible (the bigger the objective size of the mirror or lens that collects the light, the more you'll see) and the second hugely benefits from magnification. Increasing both means making the telescope bigger, and since most of us need a telescope that can be easily stored and whisked into the backyard, entry-level telescopes are always a compromise between size, weight and portability.

Focal Length and Eyepieces

It's not the size of the telescope that gives the magnification, but the eyepiece. Most telescopes come with a couple of eyepieces included, which let your eyes make sense of the light coming into the telescope's optics. Exactly what eyepiece you use also determines the magnification and the field of view of your telescope. Written on the side of each eyepiece will be a number, with the most common provided with entry-level telescopes being around 25 mm and 9 mm. This is the focal length of the eyepiece. Typically, you'll use the 25 mm to find something in the night sky, and then swap to the 9 mm to get a close-up.

Choosing a Telescope

What telescope should I buy? This is the most common question asked to any stargazer or amateur astronomer, and also the most difficult to answer. There are just so many different types of telescopes these days that it can be very difficult to choose between them. However, stargazers have it good; telescopes are relatively cheap nowadays. It is possible to spend as little as a few hundred dollars, but that doesn't mean you should take the process of choosing and buying a telescope any less seriously.

There are dozens of different types of telescope, but since this is a book on stargazing rather than advanced astronomy, let's stick to affordable entry-level models. If you want to dive straight into the high-end and spend many thousands of dollars, there is plenty of advice in other books and online. The best advice is to wait at least a year; better to try out a small telescope to see if you get the bug.

Star Parties

Try out some telescopes first. The easiest way to do that is to attend stargazing sessions at your local public observatory, if there is one, or by going along to observing sessions—often called star parties—held by your local astronomical society. The folks there will gladly let you have a go on various types of telescopes, and tell you everything you could ever

want to know about the different kinds. A quick peek at the planets through someone else's telescope may even be enough for you to get your fix.

Just as you do with your own stargazing sessions, go to a star party with an idea of what you want to learn. A vague request to "show me something amazing" every time you get near a big telescope won't get you very far; you'll be shown that season's best sights, such as the Orion Nebula, Saturn's rings or a globular cluster such as M42. Similarly, ask an experienced stargazer to show you some constellations and you'll likely be shown Orion, Cassiopeia, the Big Dipper and so on. It's better to arrive wanting to be shown double stars, constellations unknown to you, or—most likely if you're attending anywhere with big telescopes—globular clusters, nebula and other sights only visible with magnification. The rest of this book contains suggestions for those using 10-inch and bigger telescopes for precisely that reason; if such sights are beyond your equipment, save them for your next star party or public observatory trip.

Free Telescopes

For the most bang for your buck, buy a used telescope, or better still, borrow one. If you do know someone who has a dusty old telescope in a back room, ask if you can take it on loan, but promise to return it (it might be terrible!).

Either way, there are two types of starter telescopes, the refractor and the reflector.

The Refractor Telescope

Refractor telescopes use lenses. The current budget buy, a refracting telescope with a 4-inch or 6-inch lens will afford you fabulous views of planets and the Moon. From splitting double stars to getting eyes-on with faint fuzzies, a refracting telescope (Fig. 9.3) is a great all-rounder for the backyard. Refracting telescopes are completely sealed and therefore quite hard to damage, and don't need much cleaning or attention. They also often come with Go-To software (see below).

Fig. 9.3 A refractor is a versatile and compact backyard telescope, but the image is inverted, which can be disorientating. © Gill Carter

The one major disadvantage is that a refracting telescope gives you an inverted image of what it's pointed at. Scanning the sky and adjusting the telescope to get an object in the center of the field of view must therefore be done upside-down and the wrong way up. It can all be a bit much at the start. While slewing back and forth, and up and down, have a look at the sky and through the red dot finder/finder-scope (a manual aiming device that attaches to the side) to see exactly where the telescope is pointed. This will help you get used to exactly what patch of the sky it's going to show you.

The Reflector or Dob

Reflector telescopes use mirrors. A Dob is what amateur astronomers tend to call a Newtonian reflecting telescope on a Dobsonian mount. Constructed around an open tube, reflecting telescopes are much larger than refracting

telescopes, but generally gather more light, hence their reputation as 'light buckets'. If you're after more magnification that a refractor can manage, and are happy to manually control your telescope (tricky, but a surefire way of getting to learn the night sky properly), a 6-inch to 10-inch Dob makes a fine purchase, but note that it comes with the distinct disadvantage of being rather immobile. A 6-inch model can weigh around 20 kg, and a 10-inch around 30 kg.

It's possible to lighten the load of that large optical tube—and hence make it fit into the trunk of a car—by choosing a model with a truss-tube. The tube is collapsible into two parts, which makes a Dob much easier to both move to dark sky sites, and store in your home. A truss-tube design adds about a third to the cost.

What A Telescope Can Do

Like everything else, the use of both the imperial and metric system can make comparing telescopes unnecessarily difficult. Most amateur astronomers talk about their telescopes in terms of inches—they're describing the aperture, the size of the objective lens—but most telescopes have the millimeter measurement as part of their model number. So to save all the confusion, here's a simple, but surprisingly difficult to find conversion chart for telescope sizes, with a very rough guide to what you'll see through each (Fig. 9.4).

Limiting Magnitude

As we learned previously, the magnitude of an object (Chap. 5) is all-important—and that applies to telescopes as much as your own eyes. With so many objects to look for in the night sky, and with star-charts and star atlases catering to all kinds of stargazers and amateur astronomers using various types of equipment, it can be difficult to know what is within reach of your telescope.

Refractor telescopes		Reflector/Dob telescopes
70mm – 2.7-inch 80mm – 3-inch *(designed for travel)*	*Planets & the Moon*	
90mm – 3.5-inch 102mm – 4-inch	*Wide-field clusters & glimpsing galaxies*	
120mm – 5-inch 150mm – 6-inch		100mm – 4-inch 130mm – 5-inch 150mm – 6-inch
	Deep sky	190mm – 7.5-inch 200mm – 8-inch 250mm – 10-inch 300mm – 12-inch
	Observatory-grade magnification	350mm – 14-inch 400mm – 16-inch

Fig. 9.4 What the various sizes of telescopes are best used for, with metric-imperial conversions to make it easier to compare the different sizes

Limiting magnitude is the point where something becomes invisible, though exactly where that point is will wholly depend on what gear you're using. While objects of +4.5 magnitude are visible to the naked eye under most conditions, a pair of 10×50 binoculars extends that to around +9. Use a 4-inch telescope and that jumps to around +12, an 8-inch manages +14, and through a 10-inch telescope it's around +15. That's true deep sky. Mostly, this book presumes you don't have a 10-inch telescope.

Get to grips with limiting magnitude, and how it applies to you in your backyard, and you'll better be able concentrate your efforts on get-able observing targets rather than searching for something you have no chance of seeing.

The Go-to Telescope

This isn't a different kind of telescope to the ones we've already encountered, but it does take stargazing to a new level. The chance to have a computer inside a motorized refractor (only) telescope to find any one of 'tonight's best' objects from its 40,000-strong database and put it into the eye-piece—and keep it there—at the touch of a button sounds very tempting.

While such Go-To telescopes will help you find objects easily, they don't take into account your observing site's peculiarities; you could find yourself waiting for a few minutes while your telescope points itself at a tree, shed or your neighbor's window. The computers inside Go-To telescopes also often try to show you things very low on the horizon, which the vast majority of stargazers won't be able to see. You could also argue that while a Go-To telescope makes things easier in the short-term, it may well prevent you from properly learning where objects actually are the night sky. Despite their clever marketing that suggests hassle-free observing, Go-To telescopes very often have convoluted setup and orientation procedures that can sometimes dominate an observing session, especially the first half-dozen times. A lot of patience is often required, though once you've mastered them they can save a lot of time.

The Two Mounts

Telescopes usually have one of two kinds of mount; the alt-azimuth, and the equatorial. The former is found on most budget telescopes, and allows it to be tilted up and down and rotated to the left and right. On a manual telescope this is the most basic setup, though if you have a computerized, motorized Go-To model, it is relatively easy to use; as well as slewing up and down automatically until it reaches its target, a Go-To computerized telescope can also track the movement of stars, keeping your target in sight. Alt means altitude—up and down—and azimuth refers to the left and right motion. However, you still need to align a Go-To refractor telescope when using an alt-azimuth mount; as well as using a compass to point it north, you'll likely need to go through a two or three-star alignment method, which means fixing the telescope manually on bright visible stars such as Arcturus, Sirius or Capella. All very well as long as you can see three such objects from your location.

The equatorial mount is much more serious. It allows you to very easily track movement in the night sky. First you set your latitude on a dial (this fixes the height of the telescope barrel), then align one axis to the north celestial pole—Polaris, the axis of the Earth's rotation. Equatorial mounts also have motors, but there's no need for a computer; the motor will simply drive the telescope so as to cancel-out the speed of the Earth's rotation, and thus keep the target stationary in the eyepiece. However, there's a rather steep learning curve (as well as a price-hike) to equatorial mounts that make them most favored by experienced amateur astronomers and astro-photographers rather than curious stargazers.

Eyepieces and Magnification

In terms of what you can actually see in your telescope, the important figure—and one used for the remainder of this book—is magnification. If you have a 4-inch/102 mm telescope with an 800 mm focal length, and you're using a 25 mm eyepiece, it's capable of 32× magnification. If you're using a 9 mm eyepiece it's capable of 89× magnification (Fig. 9.5). 25 mm is therefore referred to as low power, and 9 mm as high power. The maths is easy; magnification = telescope focal length (mm) divided by eyepiece focal length (mm). So if you've got a monster 10-inch/250 mm telescope with a focal length of 1200 mm and both 25 mm and 10 mm eyepieces, you'll be capable of both 48× and 120× magnification, respectively.

Eyepieces of the same diameter can often be used on different telescopes to get completely different results. However, it's the eyepieces that telescope manufacturers tend to skimp on, and next year you'll probably want to upgrade the eyepieces that came in the box.

Red Dots and Bright Eyes

Most modern telescopes come with either a finder-scope or a red dot-finder on the side, which are useful for two-star alignment, or when you want to find something in the sky manually (i.e., quickly) without using any of the fancy Go-To features that your telescope may have.

Fig. 9.5 Most telescopes include a low-power and a high-power eyepiece. © Jamie Carter

Ready, Aim, Fire

A red dot finder (Fig. 9.6) is just for aiming your telescope, and has no optics; it's actually nothing more than a window. It's mounted on the side of your telescope, and if you look through it, a red laser dot will be superimposed on sky above. That shows you almost the exact place where your telescope is currently pointed at. If you know the night sky well, a red dot-finder is a great help.

Next year you'll probably want to upgrade to a finder-scope, which will give you a little magnification. A finder-scope is a very small telescope, which does makes it much easier to get a distant or faint object in its sights. However, for now keep spending on equipment to a minimum—and get outside to stargaze.

Fig. 9.6 A red dot-finder or finder-scope lets you manually aim a telescope. © Jamie Carter

One-eyed Night Vision

Don't think that using a telescope is an excuse not to bother with dark adaption of your eyes at the start of a stargazing session. It remains a critical step. Since only one eye is needed to observe targets through a telescope, some amateur astronomers put a patch over one eye for 30 minutes before heading outside.

The Moon in a Telescope

The Moon is the easiest thing to find when using a telescope for the first time. The pock-marked surface of our satellite makes it arguably one of the most rewarding sights through a telescope.

Many make the mistake of thinking that the best time to observe it is at Full Moon. Try it for yourself; point your telescope at the Full Moon and not only will the surface look rather bland, but the brightness and glare will be unbearable.

The Terminator

It's best to look at the Moon when part of it is in shadow. The line between the lit part and the dark part is called the terminator, and that is where you'll find long shadows coming off the Moon's craters and mountains; this is how you can see our satellite's surface in 3D. Each day of the Moon's orbit, the terminator will shift as it waxes to Full, then wanes to New, gradually revealing—and re-revealing—features on its surface. Moon-watching through a telescope can easily become a hobby in its own right.

Telescope Target: Crescent and First Quarter Moon

The perfect time to try out a telescope for the first time is the week after New Moon, when the First Quarter Moon will not only be visible before sunset, but won't wash-out the rest of the sky. You should be able to see shadows on the terminator, and Earth-shine (Chap. 3) on the rest of the surface (Fig. 9.7). Wait a few days and it will be a First Quarter Moon, when the Sun illuminates half of the surface, if you want to explore more. A field-map of the Moon is handy; if you're using a refractor telescope, consider getting a reverse-image map to match what you'll see in the eyepiece.

Telescope Target: Full Moon Rising

Although serious Moon-watchers advise against observing during the Full phase, there is an exception. If you're in position with a telescope pointed at the eastern horizon either on the day of, or a few days before of after, the

Fig. 9.7 Earth-shine and the shadows thrown by the terminator on the Moon's surface are fabulous first targets for a telescope. Credit: ESO/NASA/M. Kornmesser

Full Moon (Chap. 8), a short observing session is not only possible, but hugely rewarding. As its rises the brightness of the Moon's disc is dimmed for an hour or so, and it's a beautiful, muted orange. Since it's low on the horizon it's at a comfortable height to observe, though some elevation will help you spot it the second it rises. If you're observing either side of Full Moon, look out for the long shadows on its upper edges that denote that it's not quite, or no longer, in the Full phase.

The Rings of Saturn

The chance to gaze at the rings of Saturn is often the main reason that many stargazers invest in a telescope. Just beyond the reach of binoculars, even a 3-inch telescope will afford spectacular views. The sixth planet takes 29 years to orbit the Sun, so moves very slowly in the night sky. It's in the low, hard-to-find constellations of Scorpius, Ophiuchus, Sagittarius and Capricorn until the mid 2020s (until then, the southern hemisphere gets a much better view, Chap. 13), but it's bright enough to spot easily from about June through September despite being close to the horizon.

Telescope Target: Saturn

In any telescope, Saturn looks stunning. It's going to look small—probably smaller than you'd hoped—but even in a 3-inch telescope you should be able to see its spectacular rings (Fig. 9.8). If you're using an 8-inch Dobsonian or bigger, you'll likely see some of its moons, too.

As with all planets, it will drift through the field of view of your telescope pretty quickly, so you'll have to play catch-up (unless your telescope has motorized tracking). As you take in the wonderful sight of Saturn's rings, know that it's only its huge size that makes it so bright and relatively easy to see, and not its closeness to Earth. Since it's over 7 AU (Chap. 7) or one billion kilometers from Earth at its closest, when you gaze at Saturn you're seeing it as it was just over an hour ago.

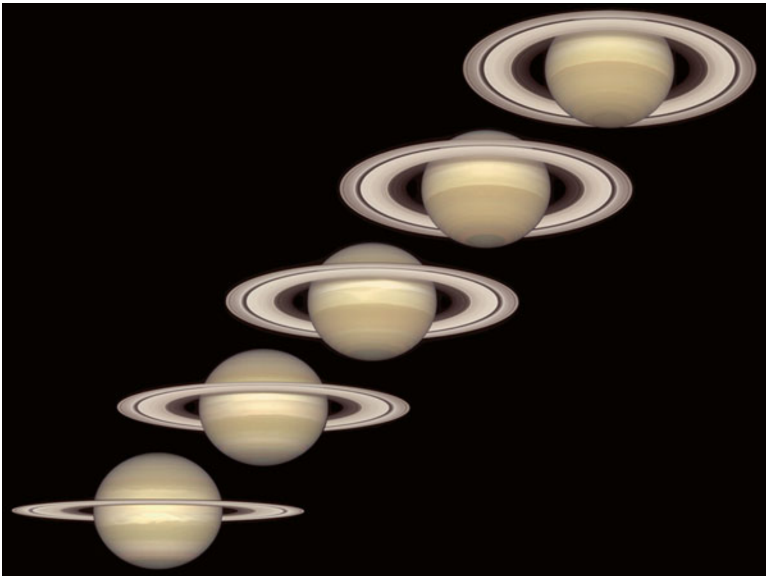

Fig. 9.8 Saturn's rings are high on most stargazer's observing lists when near a telescope. Credit: NASA and The Hubble Heritage Team (STScI/AURA) Acknowledgment: R.G. French (Wellesley College), J. Cuzzi (NASA/Ames), L. Dones (SwRI), and J. Lissauer (NASA/Ames)

Averted Gaze Through a Telescope

We've mastered this technique with binoculars (Chap. 4), but how averted gaze works with a telescope is slightly different because instead of seeing in stereo, you're using only one eye. The peculiarities of the human eye is the reason why averted gaze works, but the cure is different when peering through a telescope. If you're using your right eye to look through a telescope, glance slightly to the right when looking at dim, fuzzy objects and clusters where brightness is everything. If you look through a telescope with your left eye glance to the left. Exactly how far you avert your gaze will depend on your own eyes; experiment and, with practice, you'll find what works best for you.

Note that averted gaze is not always necessary; if you're looking for color—such as in the case of Albireo (see below)—don't use averted gaze, because your peripheral vision is less sensitive to color.

The Colorful Double

Ask anyone with a telescope to show you something wonderful in the night sky at this time of year and you'll soon be shown Albireo. The reason this double star is a clear favorite is it's contrasting color. Seen with the naked eye this star, smack in the center of the Summer Triangle, looks like many others, but put some magnification on it and it's revealed as an entrancing multi-colored double star system.

Binocular and Telescope Target: Albireo

About 380 light years distant and almost equidistant between Deneb, Vega and Altair, Albireo—the tip of Cygnus the Swan's head (Chap. 7)—can be split into two using 10× binoculars, but is much easier in a telescope. This true binary is also very easy to find if you know your constellations and major stars (Fig. 9.9). The larger star, around 430 light years distant, looks gold while its smaller counterpart is blue-green; it's a beautiful contrast.

Fishing for Stars

If you can't find what you're looking for in the night sky, there are two tactics. One way is to increase the field of view; a bright object will be much easier to find in a 25 mm eyepiece than a 15 mm or 9 mm eyepiece. Once you've centered the telescope on your target, you can then experiment with higher power eyepieces. However, if your target is a faint fuzzy, widening the field of view probably isn't going to work; while the target may be technically visible, it may not be bright enough for you to spot. So go with the higher power eyepiece and hunt around—if it's faint, there's a greater chance of you finding it.

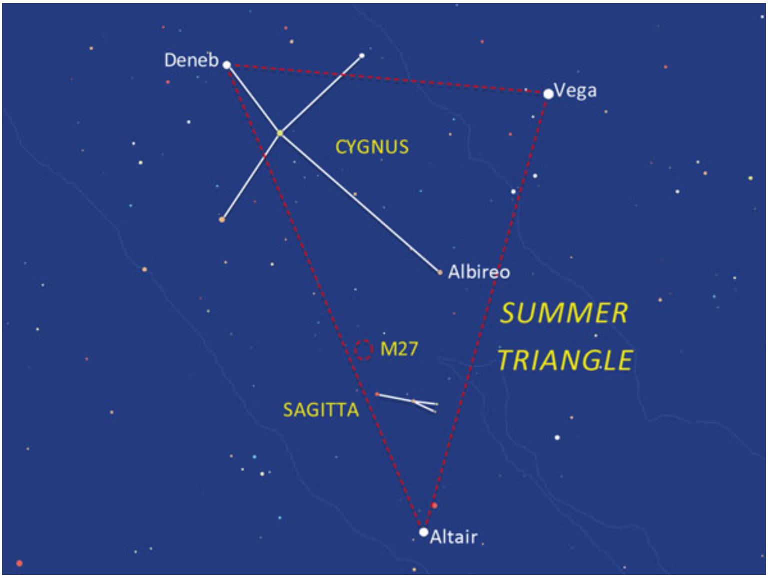

Fig. 9.9 How to find colorful double star Albireo and the Dumbbell Nebula (M27), both within the Summer triangle

Using Handrails

Get into the habit of studying a star-chart or phone app (on night mode and with the brightness turned down, naturally), then using binoculars to locate the region of sky where your target is before finally trying to aim your finder-scope. If you have trouble finding an object that you can easily find in your binoculars, use a handrail; line-up the object with the roof of your house, the top of a tree, or a telegraph line. This can make it much easier to find, and keep finding, something faint. Just bear in mind that your telescope is going to be lower than you, so will have a different perspective. This approach only works if your telescope is relatively lightweight and can be moved easily around the backyard.

Binocular and Telescope Target: The Dumbbell Nebula, M27

With a limiting magnitude of +7.5, this planetary nebula can be glimpsed in binoculars or a small telescope. First find the arrow-shaped constellation within the Summer Triangle, Sagitta (Chap. 8), and you can gaze at the finest example of its kind (Fig. 9.9).

Called the Dumbbell Nebula because of its shape, M27 is a white dwarf star; once like our Sun, this star emptied of hydrogen and expanded to become a red gas giant (much like Betelgeuse). It's that gas that's now being illuminated by what's left of the star, which is now a white dwarf. It's called a planetary nebula because its greenish look is similar to the color visible when looking at Uranus and Neptune (Consolmagno and Davis 2011).

The Riddle of the Nebulae

Is it a planet or a comet? No? Then it must be a nebula! A Latin word meaning cloud, nebula was a catch-all term for astronomers with far weaker telescopes than we have today. The march of time and discovery has seen the Andromeda nebula become the Andromeda galaxy (Chap. 10), and though the term nebula still does mean a cloud—specifically one of interstellar dust and gas—there are different types you can glimpse in the night sky. Some nebula are star-forming regions, such as the Orion Nebula, others are clouds of dust lit-up by passing stars (called an emission nebula), while others still are the leftovers of a star that went supernova. It's the latter that's termed a planetary nebula, despite having nothing to do with planets aside from a blue-green look that's reminiscent of Uranus and Neptune (Chap. 10).

As a stargazer, all you need to know is this; nebulae are usually faint, small and hard to find. Unless you've got a mighty telescope, nebulae are perhaps best left until you're more experienced. There is, as ever, one massive exception; the Orion Nebula, which is now mere months away (Chap. 12) from returning to dominate the night sky. If you've invested in a telescope, you're in for a treat.

Reference

Consolmagno, Guy & Davis, Dan M. Turn Left at Orion: 4th Edition. Cambridge University Press, Cambridge. 2011.

CHAPTER 10

OCTOBER: THE ANDROMEDA GALAXY

The Stars of October

With the nights dark and long, and the cold temperatures yet to kick-in in the northern hemisphere, there's plenty of time to both stargaze and get more experience with a telescope. This month we say goodbye to Bootes and Hercules, while the Summer Triangle gets lop-sided in the west, though if you're up late (time flies when you're operating a telescope!), you've likely noticed some stars that are familiar to you beginning to rise in the east. By the end of the month at midnight, the Winter Triangle will be visible once again, which marks the end of a year of new sights. Before the sky starts to repeat itself, there is one more, extra special sight; the Andromeda galaxy. As you get more experienced at stargazing and begin to build-up a small arsenal of optical aids, it's possible that spotting constellations is becoming less of an attraction. By now, you probably want to look at more obscure objects. With Andromeda comes a chance to see something truly spectacular, while October also brings a bevy of double stars, a suite of water-based constellations, and even some remote planets to fill-up the ever-earlier observing sessions that fall brings.

This month we'll also photograph the Moon, not with expensive astrophotography equipment, but with just a smartphone. The results will astound you (Fig. 10.1).

Iridium Flares and Shooting Stars

Thought you saw a shooting star? Perhaps you did—they're not uncommon at any time, particularly in October—but if it was more a glint than a fireball, there's a good chance that what you saw was an Iridium flare.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_10

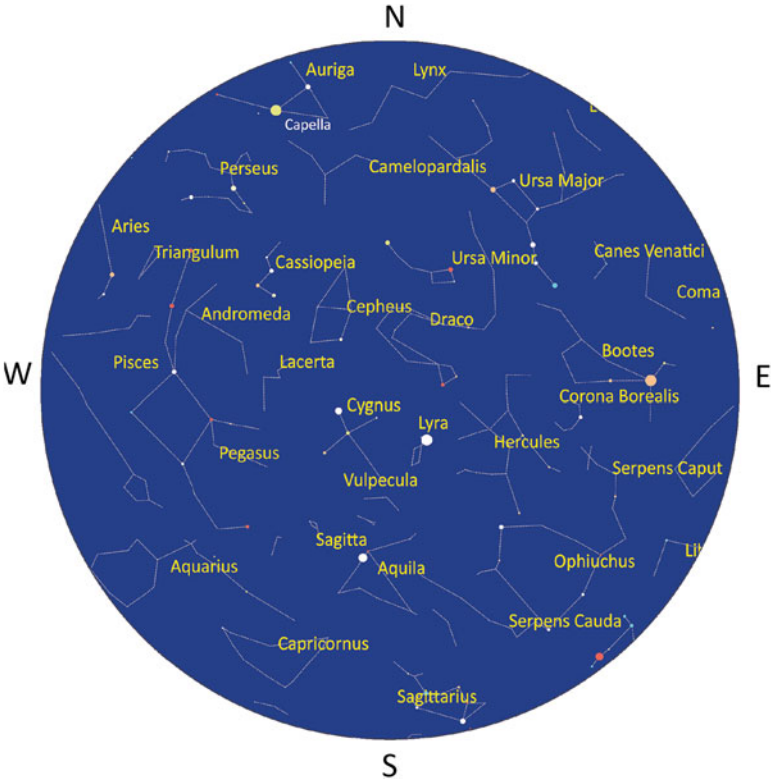

Fig. 10.1 Star-chart for October 1 at 10 p.m.

Naked Eye Target: Iridium Flares

The 60+ members of the Iridium constellation of sat-phone orbiters are of particular interest to satellite-hunting stargazers because they're odd shape means they catch the Sun's rays in a peculiar—but predictable—way, causing a momentary flare that can be as bright as a planet. The Heavens Above website[1] is the place to go if you want to witness an Iridium flare; it will give you exact times and a star-chart customized to your exact location. It's only a brief show, but it's worth putting an Iridium flare or two into a stargazing schedule one night.

[1] http://www.heavens-above.com

The Draconids and the Orionids

However, if you thought you saw a shooting star, it's very possible that you did. Neither the Draconids (which peak around October 8) or the Orionids (October 21–22) are particularly reliable, but expect a stargazing session timed to coincide with either to see a smattering of bright meteors. To see the Draconids, be in place just after dark and stargaze in the direction of—you guessed it—the constellation of Draco (Chap. 4), though don't expect more than a couple per hour. Coming from Orion, the Orionids (a leftover from Halley's Comet, see Chap. 5) tend to be more numerous and fiery. Can't see Orion? You won't at 10 p.m.; it doesn't rise until midnight, which makes the Orionids a late-night or early morning mission.

As ever with meteor showers, check with the Moon, which can very easily wash-out both the Draconids and the Orionids.

Good Seeing

When stargazers talk about the night having good seeing, they're not talking about whether the sky was cloudy or clear. Clouds might be the most common reason for abandoning an observing session, but there are other meteorological hazards in the skies above that can make the stars more difficult to observe.

Seeing refers to how turbulent the atmosphere is. If you look at a bright star low on the horizon, such as Sirius in winter or Spica in spring, you will notice them twinkle. This is because you're looking through a dense part of the Earth's atmosphere; you're looking at the star through more moving, and much warmer, air than when you look directly upwards at the zenith. That moving air interrupts the path of light from the star to your eyes. However, if it's windy there is likely to be a lot of moving air all around you, so the stars above will twinkle, and be slightly blurry. This turbulent air constitutes poor seeing, and it's the reason why big telescopes tend to be on the tops of mountains, well above the most turbulent part of the Earth's atmosphere.

As a vague rule of thumb, if it's been raining, or is predicted to rain near your observing location later that night, the chances are that the winds will

be stronger than normal, so seeing could be a problem. However, rainstorms and cold fronts often clear the atmosphere of dust, which can lead to a very clean, pristine atmosphere ideal for stargazing.

A lot will depend on where you observe from, and pure luck, so don't let worries over seeing interrupt your plans too much. Just bear in mind that even in clear skies stargazing can sometimes become a blur. You can maximize your chances of clarity by observing stars and planets when they're highest in the sky; Jupiter or Saturn at the zenith is far clearer than when just above the horizon. The wait for good seeing is why having telescope often means going to bed very late, or getting up in the small hours.

In Search of Andromeda

Stare at the Andromeda galaxy and not only are you looking at the light from 2.5 million light years ago. You're also seeing the largest galaxy in our neighborhood that compares to our own; what astronomers know about the geography and evolution of the Milky Way has much to do with what they've been able to learn from looking at this close spiral galaxy.

Star-Hop: The Great Square of Pegasus to the Andromeda Galaxy

Find the Great Square of Pegasus, whose top left star is Alperatz (Fig. 10.2); go two bright stars left and range your binoculars up to find a milky patch—the Andromeda galaxy.

Star-Hop: Cassiopeia to the Andromeda Galaxy, M31

No luck? Try another way. Find Cassiopeia high in the sky, and use the second V-shape (if you look at its five stars as a W shape) to make an arrow, with Shedar at its point (Fig. 10.2). That arrow points directly at the Andromeda galaxy.

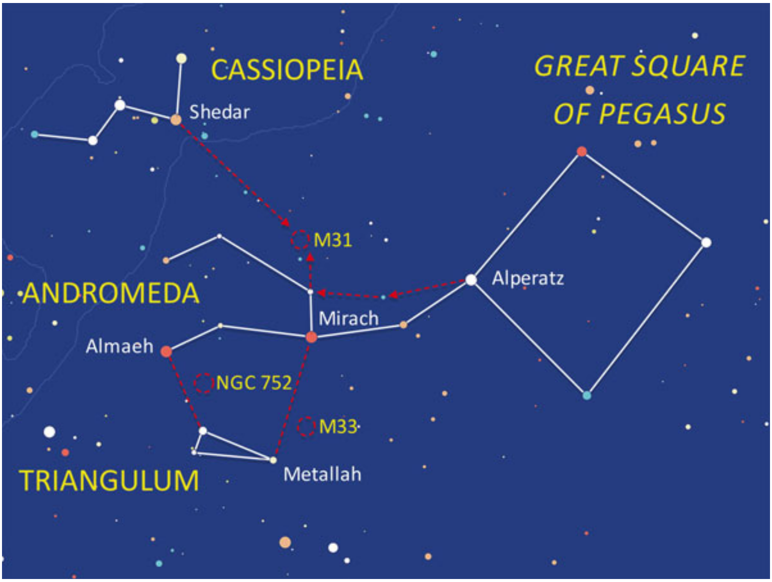

Fig. 10.2 How to find the Andromeda galaxy (M31), Triangulum galaxy (M33) and NGC 752

Naked Eye and Binocular Target: The Andromeda Galaxy, M31

To see its fuzziness and bright center through binoculars is one thing, but don't ready your telescope just yet—this is just as much a target for the naked eye and binoculars. Without moving your eyes from M31, take the binoculars down; if you're in a dark sky site, you'll see it with your own eyes, too. This is the furthest object you can see with the naked eye. Avert your eyes (Chap. 4) to see more of its bright core in your peripheral vision.

Telescope Target: The Andromeda Galaxy, M31

Seen it? Now see it again in close-up. It's a target that looks best in a low-power eyepiece, but take your time. When you get it in the eyepiece it can initially be disappointing, and not much brighter than in a pair of binoculars. However, use the averted vision technique and you will see a lot of brightness coming from the disc. It's the combined light of a trillion stars.

Those stars, which can be seen as a vast disc in photographs, are actually stretching right across the field of view in a 25 mm eyepiece; M31 is a lot bigger than it looks. However, your eyes expose for the intense (in comparison) brightness at the center of the galaxy, and in doing so, they don't receive the light from the surrounding discs. To put it another way, if you pointed a camera at the Andromeda galaxy and opened the shutter for 10 seconds it would show a great deal more light than your eye can see. Averted vision helps redress that balance, though only slightly.

Tempted to zoom in by using the high-power eyepiece? Have a go, but don't expect to resolve individual stars in a small telescope. It's a lesson in light; by increasing the magnification, you lessen the brightness. You'll probably find that focusing your telescope is difficult and the image is less inviting than the wider field of view (Fig. 10.3).

The Andromeda Galaxy's Dramatic Future

M31 is headed straight for us at 250,000 miles per second (NASA 2013), and as it gets closer, it will begin to dominate the night sky. Sadly for stargazers that won't be for another 3.75 billion years, and the Andromeda-Milky Way collision won't begin for about four billion years. Since our own Sun will have spent its fuel in about five billion years, this is all of little concern to humans, but it's a measure of astronomers' computer models that they can plot the cosmic future so accurately.

Cosmic collisions aren't what they're cracked up to be; the immense space between the stars in both galaxies means that no stars will actually crash into each other, though gravity will drastically change the position and orbits of stars. A few billion years later both galaxies will be one as M31 and the Milky Way get shredded and re-made.

Fig. 10.3 In a few billion years M31 in Andromeda will be so close to the Milky Way that it will cast galaxy-shadows on Earth. Credit: NASA; ESA; Z. Levay and R. van der Marel, STScI; T. Hallas, and A. Mellinger

The Triangulum

High in the eastern sky this month, and directly below the constellation of Andromeda and M31, is the tiny constellation of Triangulum, whose name gives a clue to its basic shape. Nearby is the Triangulum galaxy, M33, the third-largest galaxy in the Local Group after the Andromeda galaxy and our own Milky Way.

Naked Eye Constellation: Triangulum

You'll find Triangulum about halfway between Perseus and the Great Square of Pegasus, with bright star Metallah at the head of the triangle (Fig. 10.2). To its left are the other two stars, brighter Beta Trianguli and dimmer Gamma Trianguli. Take a careful look at the latter (then use

binoculars) and you'll find that it's actually a loose optical triple star. Although it's far smaller than the surrounding constellations, it's worth getting a fix on Triangulum to guide you straight to two stunning deep sky sights.

Binocular and Telescope Target: The Triangulum Galaxy, M33

It is possible to see this, the third largest galaxy in the Local Group (see below), with the naked eye. At almost three million light years away that would make it the most distant object you can see without binoculars or telescopes, but good luck finding it without either of those (put it on your observing list for the next time you're in the middle of a desert/on top of a mountain at night). Even with binoculars, M33 can be tricky, but give it a try because it's relatively simple to locate at this time of year; visualize a line from Metallah up to Mirach in Andromeda, and a third of the way there, look at the extreme right of your binoculars' field of view (Fig. 10.2). You'll see a misty patch in binoculars, and using a modest telescope, four stars in a kite-shape with a faint light within (Consolmagno and Devis 2011).

Binocular Target: Open Cluster NGC 752

Just so you know you've not confused the Triangulum galaxy for something else, there is an intriguing open cluster close by. Find it to the side of a visualized line from Beta Trianguli to Almach at Andromeda's foot (Fig. 10.2). Around 1300 light years distant, it's at its best in binoculars rather than a telescope, and a haven for double stars. If you decide to invest in 15×70 or similarly high magnification binoculars (Chap. 12), NGC 752 is worth returning to.

Horse to Water

You can by now easily find the Great Square of Pegasus, so it's worth looking underneath it for two asterisms within what are known as the wet constellations, Aquarius the water bearer and Pisces the two fishes. Both of these

constellations are faint, but as high in the south this month as they ever get. Aquarius and Pisces dominate this area of the sky, known to stargazers as The Sea, which also includes the beautiful constellation of Delphinus the Dolphin (Chap. 7) as well as two that get lost in the horizon's haze for almost all stargazers in the north, Cetus the whale and Eridanus the river.

Naked Eye Target: The Circlet Asterism, Pisces

Pisces is two lines of dim stars, so find the Circlet and you've got the interesting section. Looking south-west, the Circlet is directly underneath Pegasus; find the two lowest points of the Great Square, Markab to the west and Algenib to the east, and from the mid-way point between them, drop down to five stars of equal brightness—and a couple of dimmer flankers—that together make an oval shape (Fig. 10.4).

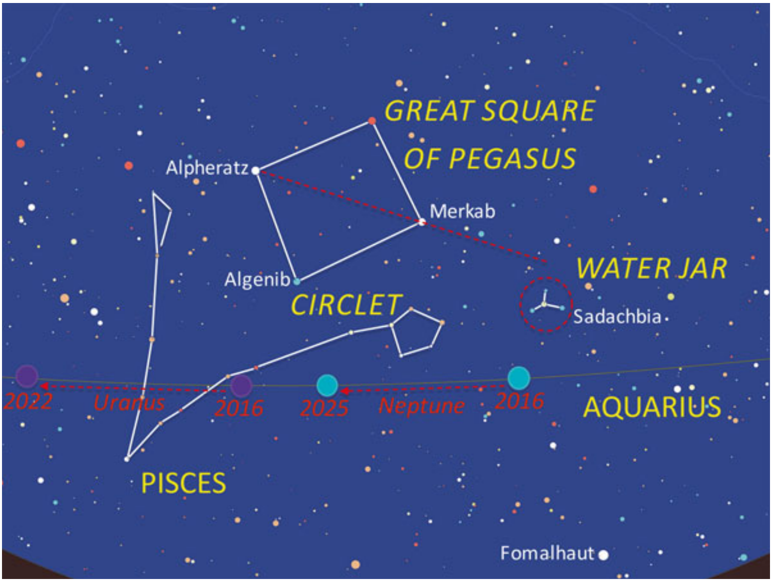

Fig. 10.4 In an area of the sky called The Sea by stargazers is the Circlet in Pisces and the Water Jar in Aquarius, above 'Royal Star' Fomalhaut. Also shown are the rough positions of Uranus and Neptune from 2016 onwards

What Is the Age of Aquarius?

Ever heard the expression the Age of Aquarius? It will follow the present Age of Pisces and it's an astrological—and not an astronomical—term that merely relates to where the Sun is during the vernal equinox (Chap. 3). After a couple of Millenia of the Sun being in the constellation of Pisces during late March, it's now creeping towards the constellation of Aquarius. Astrologers use this to determine a defined astrological age, but what it really teaches us about is Earth's own precession (Chap. 6). So the Sun's apparent drift into Aquarius on this one day—and only from Earth's point of view—is inevitable, though talk of a supposed Age of Aquarius is rather premature; the official boundaries of the constellations means it will take around 500 years before it begins.

Binocular Target: Water Jar Asterism, Aquarius

The Circlet is supposed to represent the head of a fish, which rather conveniently points west towards our next target, four stars that are arranged in the shape of what looks more like a cocktail glass. Traveling diagonally west down to the horizon, the Water Jar is a little west of the Circlet. Another way to get there is to visualize a diagonal line from the top-left to the bottom-right of the Great Square (Alpheratz to Markab), and go the same distance again (Fig. 10.4). The Water Jar is just beneath that point, and fits well in the field of view of 10 × 50 binoculars.

Sadachbia is the star at the base of the asterism (Fig. 10.4); it's around 158 light years distant and very similar to Vega (Kaler 2015). There's little to see elsewhere in this faint constellation—and zero Messier objects—though at least Aquarius does give us July's Delta Aquarids meteor shower (Chap. 7).

Look directly below Aquarius this month, low to the horizon, and you may spot Fomalhaut (Fig. 10.4), one of the Royal Stars (Chap. 5 and Chap. 7). It's 25 light years distant and one of the top 20 brightest stars in the night sky, so it might just peek through a hazy horizon depending on your latitude.

Ice Cubes and Icy Giants

While we're in the watery confines of Aquarius and Pisces, it's time to look first for a couple of ice cubes—an easy double star within the Water Jar—and begin what can become an annual search for the two icy giant planets in the solar system, Uranus and Neptune.

Telescope Target: Zeta Aquarii Double Star, Aquarius

Just above Sadachbia, and at the center of the Water Jar asterism (see above) is Zeta Aquarii, also called Sadaltager (Fig. 10.4), which you should be able to see as a naked eye star. It's actually a true binary star system, and can be split into two sparkling white stars quite easily with a 4-inch telescope and a high power eyepiece. It's reckoned that these two stars—around 103 light years distant and of equal brightness—orbit each other every 760 years from 140 AU apart. The Zeta Aquarii star system also shows precession (Chap. 6) in action. Until 2003 it was in the southern celestial hemisphere, before crossing the celestial equator (Chap. 3) and entering the northern celestial hemisphere (Kaler 2015).

Glimpsing the Ice Giants

While the stories behind constellations and the major, bright planets go back thousands of years, the seventh and eighth planets belong only to science. Ancient man had no knowledge of either Uranus or Neptune, which were discovered in 1781 and 1846, respectively. Both are tiny and not the most impressive objects you'll ever see, but anyone wanting as full an appreciation of the solar system as possible will want to cross them off their observing list. They're most easily found when the Moon or other planets occult them, or are close-by on the ecliptic. Since the orbits of Uranus and Neptune are slow (84 years and 165 years, respectively), for the moment, they can only be easily viewed in fall (Fig. 10.4) when Earth is between them and the Sun.

Binocular Target: Uranus

At magnitude of around +6, Uranus is binocular object if you know where to look. It is moving through the constellations of Pisces and into Taurus between 2016 and 2030 (Fig. 10.4). It is therefore visible in fall and early winter. A good time to look for it might be 2024 through 2026 when it's close to the Pleiades; in 2026 it's mid-way between Aldebaran and the Pleiades. Another easy way is to find out from astronomical calendars when the Moon or other planets will next be in a conjunction with Uranus; both pass by very close fairly often. Though the brightness of the Moon reduces the visibility of the planet to the naked eye, it can be used as a handrail (Chap. 9) for more easily finding Uranus in a telescope. Features on the surface of this giant planet are way beyond the reach of binoculars (it's a whopping 19 AU from the Sun), but you should be able to discern a slight blue-green color.

Telescope Target: Neptune

At magnitude of +8, the blue planet is just reachable by a small telescope, and it really does look blue. From 2016 until 2030 it's a constellation or two behind the orbit of Uranus, residing in Aquarius and Pisces just below the Water Jar asterism in Aquarius and the Circlet in Pisces (Fig. 10.4).

The Local Group and Beyond

Despite its lofty reputation, Andromeda isn't the nearest galaxy to the Milky Way. In fact, there are at least 30 other galaxies closer to us. Most of them are dwarf galaxies, defined as such because they have fewer stars,[2] such as the Small Magellanic Cloud and the Large Magellanic Cloud (Chap. 13). The majority of the closest galaxies are satellites of the Milky Way. These 30-or-so galaxies make-up a small galaxy cluster called the Local Group by astronomers, which measures about 10 million light years across.

[2] Just a few billion compared to the 200 billion in big galaxies like the Milky Way and the Andromeda galaxy.

Beyond the Local Group

We can also make-out fainter galaxies that aren't part of the Local Group; the M81 Group (see below) is one of the nearest galaxy clusters to the Local Group. There are three other loose groups of galaxies within 20 million light years of us.

Just as stars are named after the constellations they appear to be in rather than their actual position, galaxies, galaxy clusters and galaxy super-clusters are also named after their line of sight companions. Thus we have the Virgo Cluster (Chap. 6), the Ursa Major Group and the Leo Group. The Local Group, the M81 Group and the other three galaxy groups close to us are all outlying members of the Virgo Cluster (Chap. 6), also known as the Local Cluster.

That's the easy bit. This Virgo Cluster, together with the nearby (in cosmic terms) Fornax Cluster and hundreds of galaxies in between, form what's known as the Virgo Supercluster (Fig. 10.5) or Local Supercluster, which spans about 110 million light years. Galaxy superclusters like the Virgo Supercluster are chains of around a dozen galaxy clusters (NASA 2004), of which there are estimated to be about 10 million of in the Observable Universe.

That's likely a vast understatement. While the Observable Universe is about 90 billion light years across, cosmologists predict that the actual Universe is around 250 times bigger (Vardanyan et al. 2011).

The distances involved is beyond comprehension, but it does at least demonstrate that anyone with a working knowledge of the major constellations in the night sky can begin to navigate the known Universe.

Urban Galaxy Hunting

Distant galaxies containing billions of stars must be easy to see with a telescope, right? From urban areas, that's sadly just not the case, with faint fuzzy galaxies often looking fainter and fuzzier with higher magnification—and that's if you can find them to begin with. Reliable galaxy-spotting requires inky black skies, and at least an 8-inch or 10-inch telescope, most of which aren't easy to transport. If you really want to rack-up 800+ galaxies, only a 16-inch telescope will do.

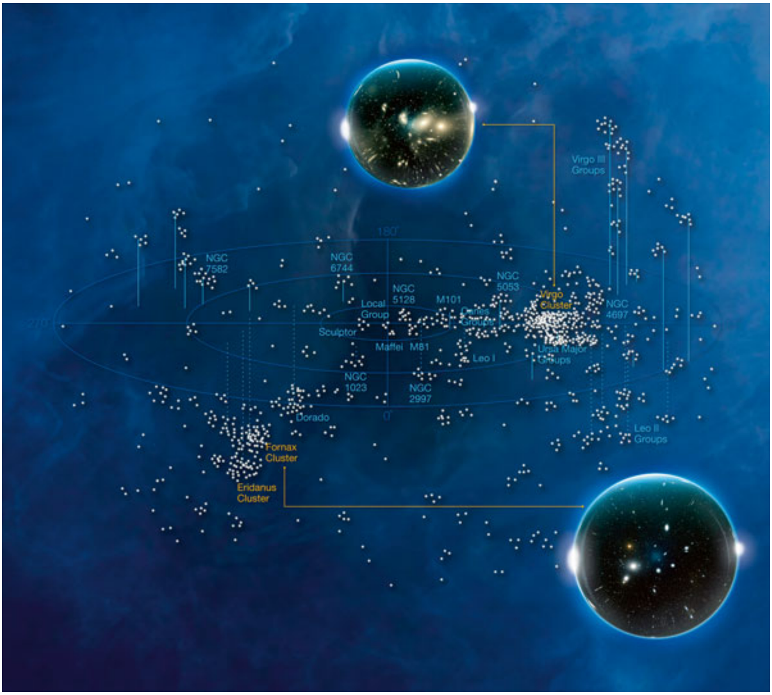

Fig. 10.5 The Virgo Cluster and the Fornax Cluster dominate what's collectively known as the Virgo Supercluster of galaxies, which all lie within 100 million light years of the Milky Way. The Local Group is shown in the center. Credit: ESO

There are exceptions; aside from the Andromeda galaxy, there's a remote galaxy near the Big Dipper that's worth looking whatever size of telescope you have access to.

Telescope Target: Bode's Nebula, M81 and the Cigar Galaxy, M82

Also in the Virgo Cluster, but separate from the Local Group is the M81 Group. This galaxy cluster close to us in cosmic terms at 12 million light years, and includes the M81 and M82 galaxies. Both can be glimpsed.

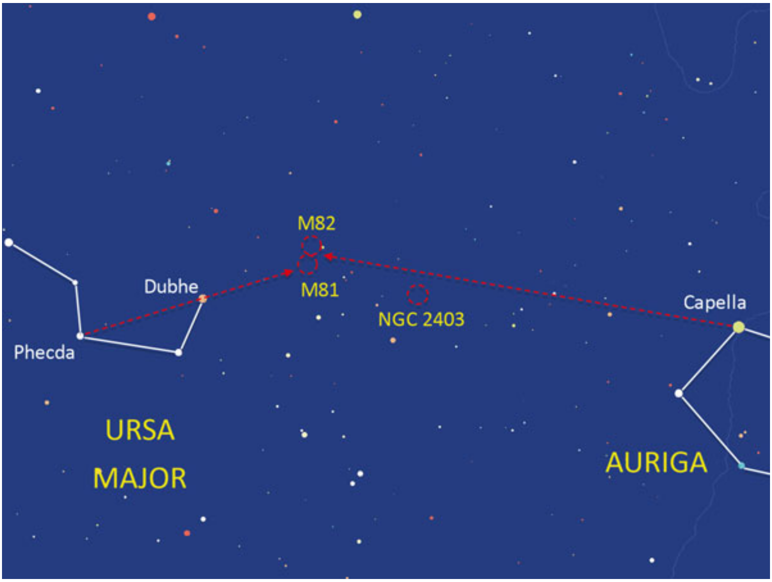

Fig. 10.6 Bode's Nebula (M81), the Cigar galaxy (M82) and galaxy NGC 2403 are all members of the M81 Group of galaxies, which also form part of the Virgo Cluster

Visualize a line that goes from the bottom of the Big Dipper's bowl to the top, from Phecda to Dubhe, one of the pointer stars (Fig. 10.6). Go the same distance again in the same direction and you'll come to the location of M81, an oval-shaped galaxy bigger than the Milky Way. Try for it in binoculars first—it's +6.8 magnitude—then point your telescope (minimum 4-inch, though in a 10-inch it looks fantastic). Averted vision is needed to get a sense of the brightness around the core, but to see something so distant and 'galaxy-like' is truly stunning. If you can't see it, stay up very late, or make a note to look for it next spring when it will be higher in the sky. Just above M81, also in the M81 Group, and in the same field of view in binoculars is M82, the Cigar galaxy (which we see side-on, hence the name), though at 8.4 magnitude it's harder to see, especially if viewing from an urban area. There are about 30 other members of the M81 Group, of which another one, NGC 2403 (see below) is also easy to find.

Why Is a Galaxy Sometimes Called a Nebula?

We've come across confusion about what a nebula is before (Chap. 9). Just to confuse you more, some galaxies are also called nebulae. The classification of some galaxies as nebulae is a historical mistake that is reflected in the names of some objects in the night sky. The mistakes are merely the result of improved magnification in modern astronomy. Telescopes years ago couldn't resolve individual stars within nebulae, and astronomers weren't able to classify them as galaxies until more recently. For instance, Bode's Nebula, M81, was named in 1774, while the Andromeda galaxy was called the Great Andromeda Nebula until the 1920s.

Binocular and Telescope Target: NGC 2403 Galaxy

Also a member of the M81 Group—and the next biggest after M81 itself—is NGC 2403, which can be seen with both binoculars and a small telescope. Visualize a line from M81 to Capella in Auriga; about a quarter of the way along is NGC 2403, which will appear as a small fuzzy patch (Fig. 10.6). NGC 2403 has a magnitude of +8.9.

Six Double Stars

In a binary star system, two stars orbit each other, and we can often detect this in binoculars or a telescope. The closer they are together, the more magnification is needed to split them. The same applies to a triple or quadruple star system, too. However, some apparent double stars are mere line-of-sight coincidences; the distance between two line-of-sight double stars can often be greater than the distance from us to the nearest of the two stars.

Since they're mere line-of-sight doubles, if you were stood on the furthest star of the two, our own Sun would appear as an apparent double star to the middle star. Although only a few seasonal examples of double stars are included for this, your first year of stargazing, there are hundreds of double

stars to look for in the night sky throughout the year. Double stars are now known to be so common that when we refer to a star by name, we're most likely talking about a multiple star system rather than an individual star.

Telescope Target: Mizar A, Mizar B and Alcor, the Big Dipper

We've looked at these two before, splitting bright Mizar from slightly dimmer Alcor in the Big Dipper with both the naked eye and with binoculars (Chaps. 2 and 4). Now we can go two steps further; even a small telescope will reveal a third, much dimmer companion of the two that make a triangle with Mizar and Alcor. However, look at Mizar through even a low power eyepiece and you'll see that it's actually a sparkling white double star itself; Mizar A and Mizar B. Though it's beyond our optics, astronomers have found these two to also be double stars themselves. Alcor has also been found to have a smaller companion. Best of all, none of these alignments are by chance; this is a remarkable sextuple system—where six Suns are gravitationally bound—and it's all happening just 80 light years or so from us.

Telescope Target: Epsilon Lyrae, the Double Double

Though it's possible to split this double star with the naked eye and binoculars (Chap. 5), a small telescope with a high power eyepiece will reveal Epsilon Lyrae, near Vega, to be not only two stars, but four; each of the stars in the double can themselves be split if you observe carefully. None of this is line of sight; this is a quadruple star system—possibly a quintuple—and only about 160 light years from us.

Telescope Target: Cor Caroli, Canes Venatici

Directly underneath Alkaid at the end of the Big Dipper is Cor Caroli in the constellation of Canes Venatici (Chap. 4). Use the finder-scope to put Cor Caroli in the eyepiece and you'll see one of the easiest double stars of all; a

large white star and a small, dimmer star with a hint of yellow. This is a true binary star system around 115 light years from us; the two stars are 67 AUs apart, and orbit each other every 8300 years (Kaler 2015).

How Common Are True Doubles?

Binary or multiple star systems, where two or more stars orbit a point between them, are surprisingly common, and could even be the norm for stars. However, don't think of double stars as small, cosy systems where one body happily orbits another; we're often talking about vast distances far larger than, say, the distance between the Sun and Pluto, and often orbital periods of many hundreds or thousands of years.

Telescope Target: Almach, Andromeda

Are double stars doing it for you? Some disagree about how fun double star-hunting is, but splitting what looks like a star into two—or sometimes into three or four—is a great way of using a telescope to its fullest capabilities. It can take a few minutes of patient observing before you see it, but if one star is much larger than the other, or they are different colors, it can be a spectacular sight. Just as delightful as the much more famous Albireo (Chap. 9), Almach is a superb sight, with even small telescopes splitting it into a bright yellow and a dimmer blue star. About 33 AU from each other with an orbital period of 63.7 years, this true binary star system is some 355 light years (Kaler 2015) from us (Fig. 10.2).

Telescope Target: Omnicron 1 Cygni, 30 Cygni and HD 192579, Cygnus

We've already split the double star Omnicron 1 Cygni and Omicron 2 Cygni with the naked eye and binoculars (Chap. 7), but put your telescope on Omnicron 1 Cygni and you'll see that this star is actually a triple star, with an orange star flanked by a white star (30 Cygni, over 600 light years from

us) and a blue star (HD 192579, over 1300 light years from us). Those pointing a refractor (Chap. 9) telescope almost at the zenith will begin to realize the disadvantage of having the eyepiece near the floor; you may need a chair, or perhaps even a cushion (wrapped in a plastic bag to avoid it getting wet) to kneel on to get a view.

Telescope Target: The Dolphin's Double, Delphinus

Range down to the south from the constellation of Cygnus to the constellation of Delphinus (Chap. 7); on the left, at the tip of the dolphin's nose—Gamma1 and Gamma2 Delphini—is an easy double star to find in a small telescope, and it's much closer to home; at only about 100 light years from us, this is a true binary system where two stars orbit each other every 3200 years from 330 AU apart (Kaler 2015).

Another Ancient Globular Cluster

One of the grandparents of the Milky Way (Chap. 5), M15 is a 33,000 light years distant object and is over 13 billion years old, almost as old as the Universe itself.

Binocular and Telescope Target: Globular Cluster M15, Pegasus

Find Gamma Delphini (above), then look to the lower-left to locate bright star Enif, the nose of Pegasus, the horse. M15 is three-quarters of the way from Gamma Delphini to Enif (Fig. 10.7). At +6.2 magnitude, in binoculars it will appear as not much more than a fuzzy star. In a small telescope, you'll see multiple stars and a bright center. M15 remains one of the oldest objects you can see in the night sky.

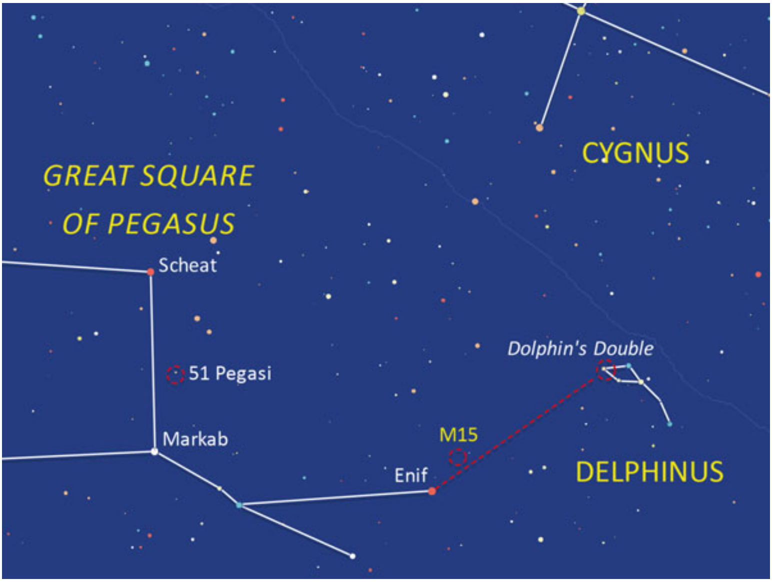

Fig. 10.7 Find the 'Dolphin's Double' star in Delphinus, then move to Enif to locate globular cluster M15

The First Exoplanet

While Lyra and Cygnus were the subject of the NASA Kepler Space telescope's hunt for Earth-like planets (Chap. 8), it was the very first planet outside of our solar system to be discovered that changed modern astronomy. Rather unusually, it's easy to see the star it orbits.

Binocular Target: 51 Pegasi

Find the Great Square of Pegasus and visualize a line between Markab and Scheat. Halfway down that line on the right-hand side (Fig. 10.7) is a seven billion year old, +5.5 magnitude yellow dwarf star called 51 Pegasi. It was found by astronomers in France to have a Jupiter-sized planet orbiting it. It was named 51 Pegasi b, also known as Bellerophon,

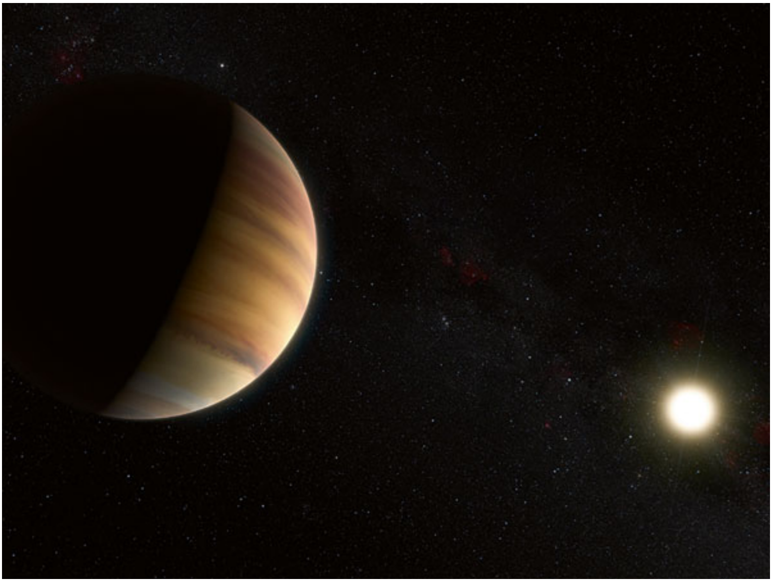

Fig. 10.8 An artist's impression of the first confirmed exoplanet 51 Pegasi b, also called Bellerophon. Credit: ESO/M. Kornmesser/Nick Risinger (skysurvey.org)

and is just 50 light years away (Kaler 2015). It takes just four days for Bellerophon to orbit its star.

Many more planets have been found since, but 51 Pegasi b (Fig. 10.8) remains one of the Search for Extra Terrestrial Intelligence (SETI) Institute's top-five candidates for radio signals from intelligent civilizations. 51 Pegasi also happens to be a star very similar to our Sun (Chap. 12).

Instagram the Moon

Astrophotography—usually using a telescope and a camera in conjunction—is one of the most expensive and complex hobbies of all, but it's surprisingly easy to do at a basic level with any telescope or mounted binoculars, and any smartphone or inexpensive compact camera.

Astro-phoneography

With either a pair of binoculars on a tripod, or a telescope aimed at the Moon, all you have to do is place a smartphone's camera optics over the eyepiece. It will need nudging until the Moon comes into view on the phone's screen, but it's merely a matter of patience. Press the smartphone's touchscreen to focus on the Moon, and take a few test shots. Either process works just as well using a compact camera.

Telescope and Smartphone Target: The Moon and Jupiter

If you used a telescope, the images of the Moon should look sharper than you ever imagined they could be (Fig. 10.9). If they're not, keep experimenting. It's worth trying to capture Jupiter in a high-power eyepiece, too; it's possible to get a Galilean moon or two in the shot.

Fig. 10.9 Just a smartphone was used to take this photograph of the Moon through a 4-inch telescope. © Jamie Carter

Mounted Binoculars and Smartphone Target: The Crescent Moon

For mounted binoculars, you're going to get a wider view and far less detail on the Moon's surface, but a stylized image of a crescent Moon between buildings or trees on the horizon can make a wonderful target for sharing on social media (Fig. 10.10). When using a smartphone to photograph the Moon through binoculars, you may need to pinch the touchscreen to zoom-in to rid the image of vignetting.

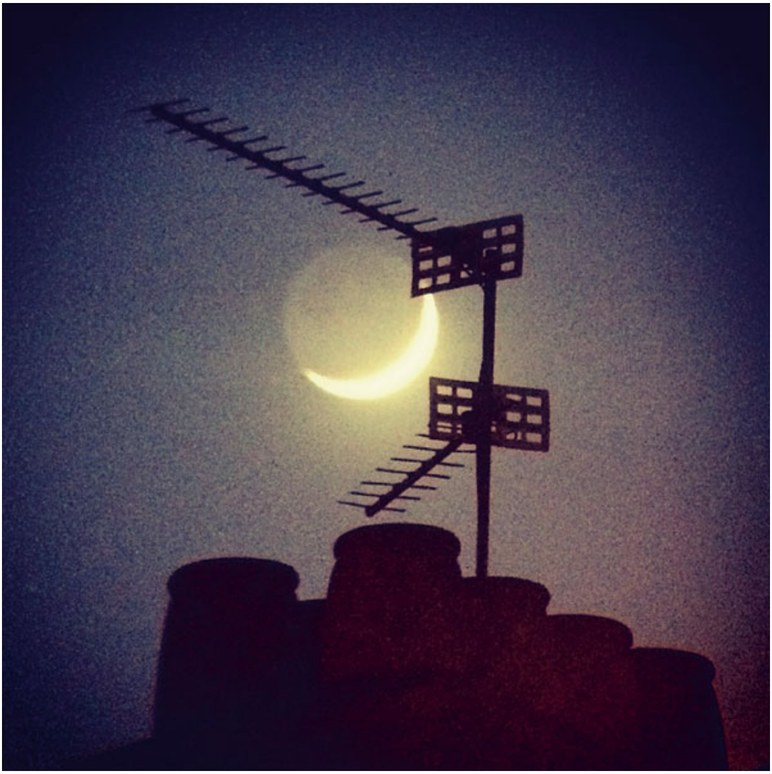

Fig. 10.10 Instagram photo of crescent Moon with Earth-shine taken using a smartphone and mounted binoculars. © Jamie Carter

Adding Accuracy

If astro-phoneography becomes a habit, there are various devices and mounts that can help position your smartphone more accurately and reliably, though most of then are manufactured for specific models of phone, binoculars and telescopes.

References

Consolmagno, Guy & Davis, Dan M. Turn Left at Orion: 4th Edition. Cambridge University Press, Cambridge. 2011.

Kaler, Jim. Stars. [ONLINE] Available at: http://stars.astro.illinois.edu/sow/sowlist.html. [Accessed 01 June 15] 2015.

NASA. NASA's Hubble Shows Milky Way is Destined for Head-On Collision. [ONLINE] Available at: http://www.nasa.gov. [Accessed 02 June 15]. 2013.

NASA. The nearest super-clusters. [ONLINE] Available at: http://heasarc.nasa.gov. [Accessed 02 June 15]. 2004.

Vardanyan, M., Trotta, R., Silk, J. Applications Of Bayesian Model Averaging To The Curvature And Size Of The Universe. Monthly Notices of the Royal Astronomical Society. Wiley. 2011.

CHAPTER 11

NOVEMBER: RETURN OF THE KINGS

The Stars of November

Recognize anything? As the Summer Triangle says its last goodbye in the west, the eastern evening sky sees the return of those sparkling stars of winter, with familiar Capella, Aldebaran, and Castor and Pollux now high in the sky by 10 pm. Below them rises Orion, easily viewable after midnight. Can you stay up late enough to get a telescope on the Orion Nebula? You can try, though we'll return to it next month when it's in prime position a little earlier, for we have another jewel to revisit—the Pleiades. A close-up of this cluster's bright stars—including Electra, Merope and Alcyone—is hard to resist, as is the chance to get Jupiter and the four Galilean moons in your the crosshairs of your telescope. Mars and Mercury get the close-up treatment, too, with help from an optional accessory for your telescope this month, the Barlow lens (Fig. 11.1).

A Mess of Meteors

As temperatures drop in the northern hemisphere, the appeal of yet more minor meteor showers might be on the wane. However, there's a good chance that any hour-long stargazing session in November will herald a fireball or two. The first half of the month see the South Taurids and the North Taurids offer a handful of shooting stars from the direction of Taurus; handy if you're planning to watch the stars of winter return to the night sky. Peaking later in the month are the Leonids, which radiate from Leo below the northern horizon and promise around ten per hour. Check astronomical calendars and websites for the exact peak dates, though the later at night you stargaze, the more shooting stars you'll likely see.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_11

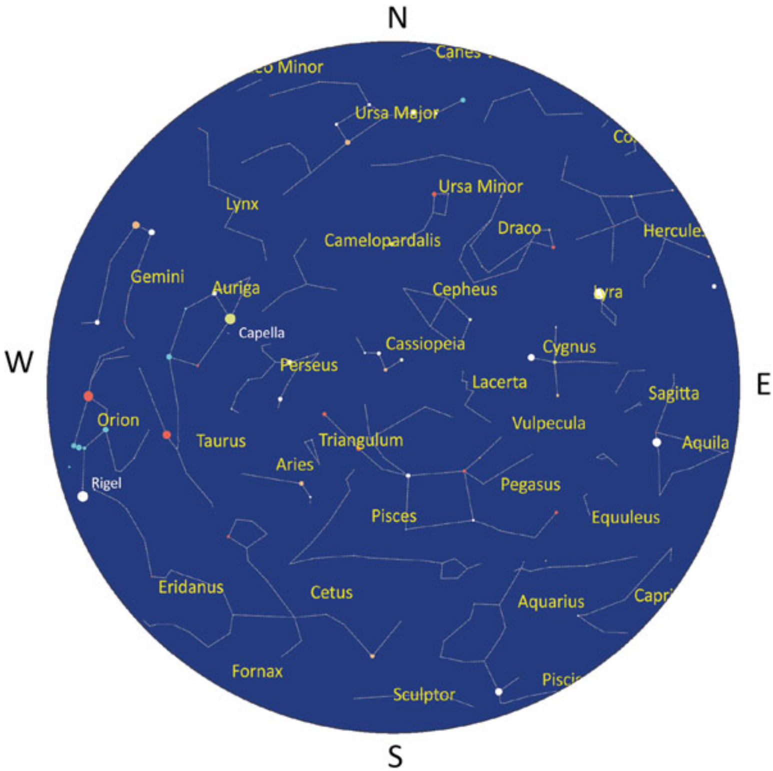

Fig. 11.1 Star-chart for November 1 at 10 pm

Return to the Pleiades

Now high in the sky again is one of the jewels of the night sky, but pointing a telescope at the Pleiades has an unexpected effect.

Binocular and Telescope Target: The Pleiades

First, have a good look at the Pleiades with the naked eye, then through your binoculars, noting how its six bright stars turns to dozens in a beautiful, busy cluster that fills the field of view. Now point your telescope into

that area. While it sparkles in binoculars, the bustle of the Pleiades is lost in a telescope. It just looks straight through it. It's a lesson in why a telescope isn't always the best option, however much it costs, but there are reasons to put magnification on the Pleiades. If you have a large telescope, you may spot some of the bright nebulosity between these huge, hot, 100 million years-young stars, which are illuminating an interstellar cloud of gas and dust the cluster is moving through. Even with a small telescope you should be able to see some double stars that binoculars can't reach.

Binocular Target: The Other Seven Sisters, the Pleiades

It may be called the Seven Sisters, but there are a lot more stars than that in the Pleiades. Most people can see six stars with the naked eye, but in a pair of binoculars four central stars really standout against a backdrop of about 30; Maia and Electra dominate the top half of the cluster at this time of year, with Merope and Alcyone at the bottom. There are actually over 5000 stars in the Pleiades. Fix your binoculars just between and below Merope and Alcyone to find the beginning of a stream of six smaller background stars in a line that decrease in brightness as you go south, with a brighter seventh star (HR1172) just below as a finale (Fig. 11.2). It looks like a bent exclamation mark.

Binocular and Telescope Target: Burnham 536, the Pleiades

A telescope isn't completely useless when observing the Pleiades. Let's look at something that does bear a close-up; a double star. Again find Merope and Alcyone in your binoculars, but this time go slightly above to create a triangle with a third star, called Burnham 536 (Stoyan et al. 2008), bang in the middle of the Pleiades (Fig. 11.2). It's a faint double, but it's definitely there. You should be able to split Burnham 536 into HD 23479 and HD 23463 with any size of telescope.

Fig. 11.2 Inside the Pleiades are the 'other Seven Sisters' (though only five are visible in this photograph) and a nice double star, Burnham 536 Credit: NASA/ESA/AURA/Caltech

The Power of Perseus

Many stargazers have a problem picking out the constellation of Perseus, but its rise is one of the highlights of fall. The confusion lies in the abundance of stars in this region of sky that don't obviously make the figure of the man they're supposed to. However, it's worth getting a fix on the wonders around and within this sparkling constellation, which lies over the Milky Way.

Naked Eye Asterism: The Fall Triangle

Finding Perseus is best done by first finding the Fall Triangle asterism using two night sky targets you already know well. Rising high in the eastern sky by 10 pm this month are Auriga and Taurus, with Perseus above. The triangle is made from going from the Pleiades across to Capella (Chap. 3), then up to Mirfak, the brightest star in Perseus (Fig. 11.3). Every stargazing season needs a triangle, and fall is no different.

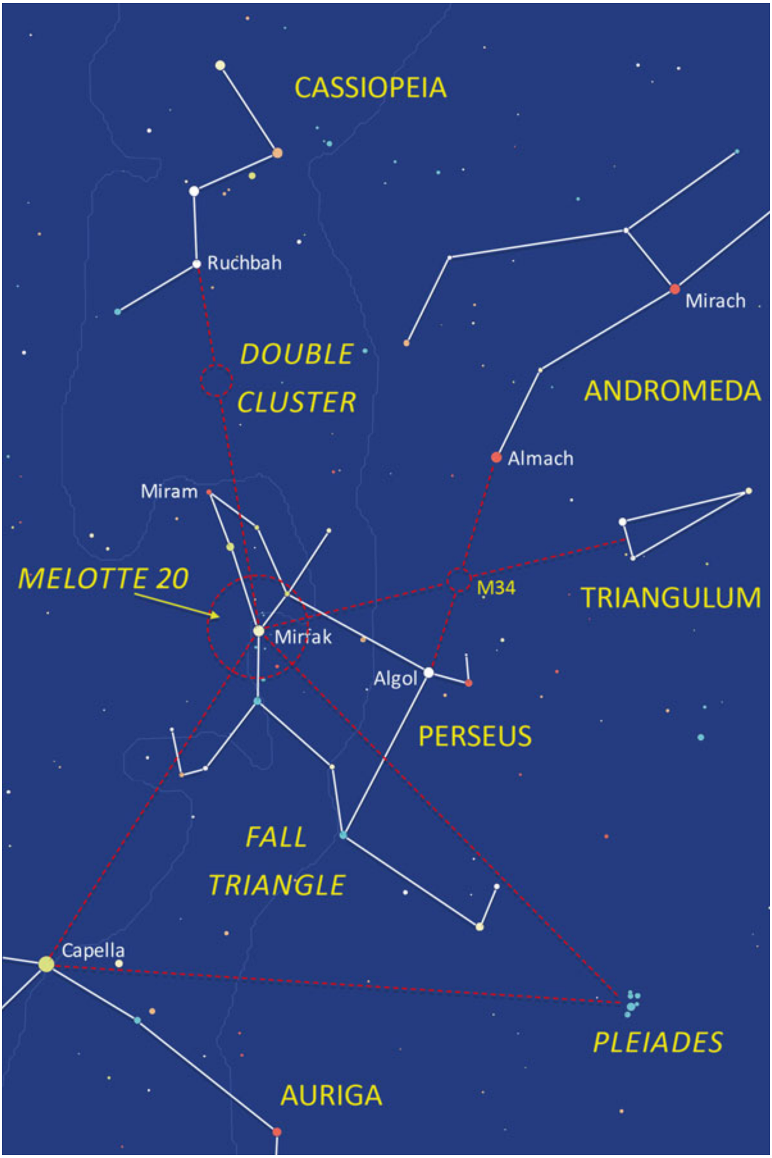

Fig. 11.3 The Fall Triangle & Perseus, which has dozens of stargazing targets including the Double Cluster, M34, Melotte 20 and an eclipsing binary star system called Algol

Naked Eye Constellation: Perseus

High in the sky in the east underneath Cassiopeia and above Auriga (Fig. 11.3), Perseus can be thought of as an upside-down V-shape, with one curved side of bright stars.

Here on the outer rim of the Perseus Arm of the Milky Way (see below), Perseus has many jewels within and around it that are perfect for both binoculars and telescopes. Perseus is also where the year's best meteor shower, the Perseids, appear to radiate from in August (Chap. 8).

Binocular and Telescope Target: M34 Open Cluster

High in the eastern sky this month is M34, an open cluster that lies around 1400 light years distant and is a good target for both 10× binoculars and a small telescope. There are two ways of finding it. The first is to sweep your binoculars along a line from Triangulum to Mirfak in Perseus (Fig. 11.3); about halfway along is this open cluster, a collection of more than 80 stars in a telescope, and around 15 especially bright stars in binoculars. The second way is to find the point about half-way between Algol in Perseus and Almach in Andromeda (Chap. 9).

Binocular and Telescope Target: Perseus Double Cluster, NGC 869 and NGC 884

We fleetingly looked at Perseus Double Cluster back in April (Chap. 4) as it was receding from view, but now it's high in the sky again it's time to get re-acquainted with this wonderful sight. Between Ruchbah in Cassiopeia and Mirfak in Perseus (Fig. 11.3), both NGC 869 and NGC 884 are open clusters with around 30–40 stars visible in each through a small telescope. There are actually over 200 in each cluster, which are both around 7500 light years distant. In any telescope they look awesome, but a wide-field view and a low-power (25 mm or similar) eyepiece is the most impactful.

Perhaps best of all, this Double Cluster is stubbornly immune to light pollution, and can be seen under almost any conditions, which makes it a candidate for putting in the top five sights you should show your friends and neighbors.

Telescope Target: Algol, the Winking Demon Star

Perseus is a must-see constellation for many stargazers because of the double cluster, but there's a reason that amateur astronomers keep coming back to its second-brightest star (see Fig. 11.3). Rather remarkably, Algol, dips in brightness for about 10 hours every few days. As we've already seen, there are many double stars in the night sky, and a great deal of them are binary star systems, but few are as dramatic as Algol. The star system actually contains three stars, though the drop in brightness is caused by one fainter star passing in front of the brightest precisely every 2.87 days [Dunlop 2004]. Algol's magnitude then drops from +2.1 to +3.4, hence its nickname 'the winking demon'. This star system—special to stargazers purely because of a line-of-sight anomaly—is around 90 light years distant.

Binocular Target: Alpha Persei Moving Group/Melotte 20 Open Cluster

Put your binoculars on the brightest star in Perseus, Mirfak, and scan the area in a circular motion. It's a jewel box of a journey. There's a small bowl of about five stars that make a cupcake (with Mirfak as the cherry) in a cluster of about 20–30 easily seen blue-white stars (Fig. 11.3), which are best appreciated as a group through binoculars. These stars are a distinct group, moving through space together, though some astronomers think they're linked to other clusters (see below).

The Local Association

You've heard about the Local Group of galaxies (Chap. 10). Now it's time for another hugely underwhelming name for some of the nearest star clusters to the solar system; the Local Association. Such are the vast distances even

in our own galaxy that if two star clusters are thought to be the same distance from us, they probably have a common origin. That's thought to be the case with M34 (see above), which is roughly as far from the solar system as the Pleiades, the Alpha Persei Moving Group/Melotte 20 in Perseus (see above), the Stephenson 1 cluster at the center of Lyra, and the IC 2602 (also called the Southern Pleiades) cluster (Chap. 13) and NGC 2516 clusters in the southern hemisphere constellation of Carina (Chap. 13). The spatial motion of all of these clusters means they could all originally be from the same stellar nursery.

The Auriga Three and the Perseus Arm

With Capella now dominating the eastern sky, but not yet overhead, November is a good time to look for three sequential open clusters that glow in Auriga.

Binocular and Telescope Targets: The Auriga Three, M36, M37 and M38

We first came across Auriga in March (Chap. 3), mentioning the three clusters lined-up ready for some magnification (Fig. 3.3). For M38 closest to the zenith—also known as the Starfish Cluster—it's X marks the spot; you'll find it where a line drawn between Capella and bright Alnath (also the tip of the horns of Taurus) intersects with a line from Al Kab to Theta Aurigae. Put M38 at the top of the field of view in a pair of binoculars and you'll see M36, also called the Pinwheel Cluster, at the bottom or just beyond. These two clusters are over 4000 light years from us, though while M36 is around 25 million years old, the stars in dimmer M38 are 10 times that age. The third member of the Auriga Three is also the brightest; M37 lies below M36, just beyond a line between Alnath and Theta Aurigae. This 300 million year old cluster is the biggest, the brightest and the oldest, and it's 500 light years further from us than the other two. In a telescope you may be able to make out an orange star at its center. If you can locate these three rich star clusters with binoculars quickly and easily, night after night, you're doing very well.

The Perseus Arm

When it comes to galactic geography, we already know that the solar system lies on the Orion Arm (Chap. 2), with the Sagittarius Arm (Chap. 8) between it and the Milky Way's core. What we haven't yet considered is what's on the other side.

The Perseus Arm—so called for its position in the night sky—is one of the two massive, major spiral arms of stars in the galaxy (Fig. 7.4). The other major spiral arm, the Scutum-Centaurus Arm, is mostly on the other side of the galaxy's center.

Laying beyond the solar system away from the center of the Milky Way, the Perseus Arm isn't bright, but stretches from Cassiopeia through Perseus, Auriga and Gemini.

Inside the Perseus Arm is the fabulous Double Cluster as well as three open clusters even fresher in your mind; M36, M37 and M38.

A Home in the Heavens

Another circumpolar constellation, and high in the north-western sky in November, Cepheus looks like a drawing of a house that a child might produce in pre-school.

Naked Eye Constellation: Cepheus

It's easy to find this mid-sized constellation from Cassiopeia; orient the latter as a W shape and you can find Cepheus above. The main part of Cepheus resembles a square, but with a fifth star in the bottom-left-hand corner (Fig. 11.4).

The brightest star in Cepheus is Alderamin (bottom right-hand corner if Cepheus is viewed as a house) at 49 light years distant, though you should get a fix on the star at the apex of the pointed-roof. Called Errai, it's above Cassiopeia orientated as the letter W (Fig. 11.4). Errai is 45 light years away, and though not especially prominent for now, that's destined to change.

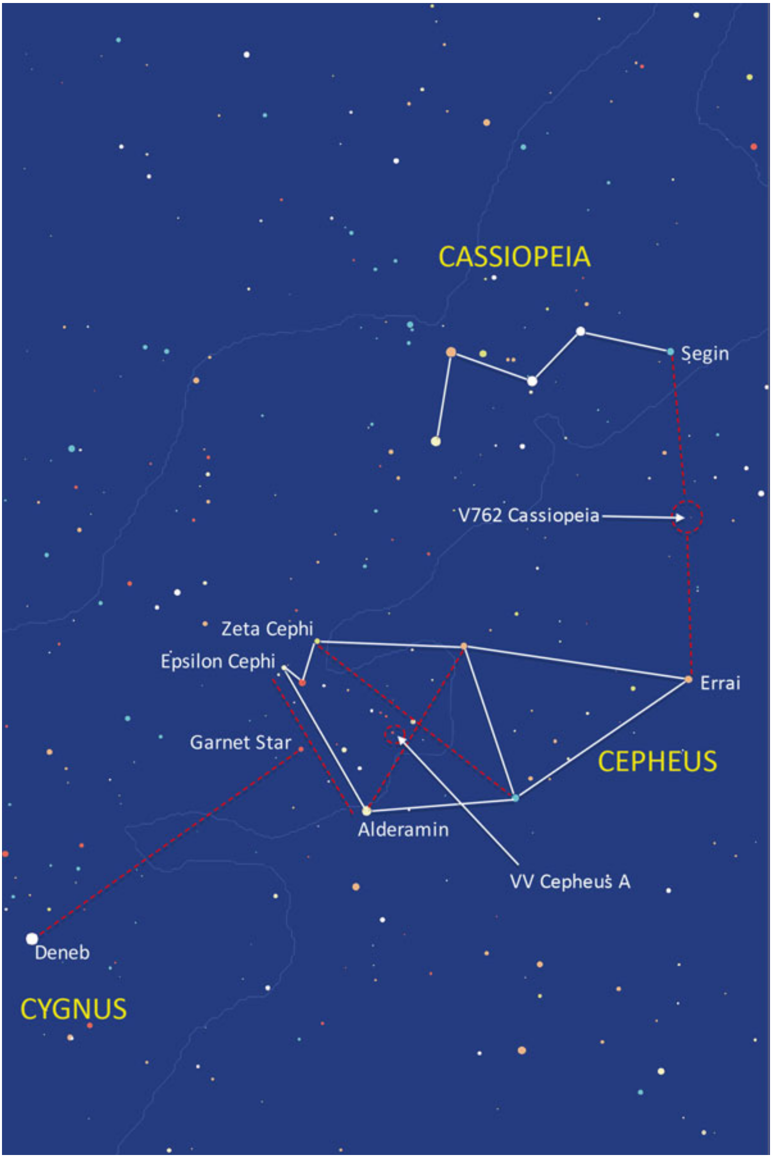

Fig. 11.4 Easily found from Cassiopeia, the constellation of Cepheus looks like a house. Around it are three of the most distant stars, the Garnet Star, Deneb & V762 Cass, and one of the biggest, VV Cephei A

Binocular Star: Errai, the Next Pole Star

It's time to think about more about precession (Chap. 6) as we encounter Errai in Cepheus, which in a few thousand years will become the most famous star in the sky when it takes over from Polaris as the north star. Errai is pretty special already; it's a double star system, and one of the few binary systems with a confirmed planet. Errai was one of the first stars where astronomers found a planet, and it remains the brightest star with a confirmed planet [Kaler 2015].

After Errai, the north celestial pole of Earth will move counterclockwise on its 26,000 year-long circular journey to Alderamin, also in Cepheus, then close to Deneb and Vega (Fig. 11.5). Thuban (Chap. 6) in Draco (Chap. 4) and Kochad, one of The Guardians in Ursa Minor (Chap. 4) will then herald the return of Polaris as the north star once again in around 26,000 years.

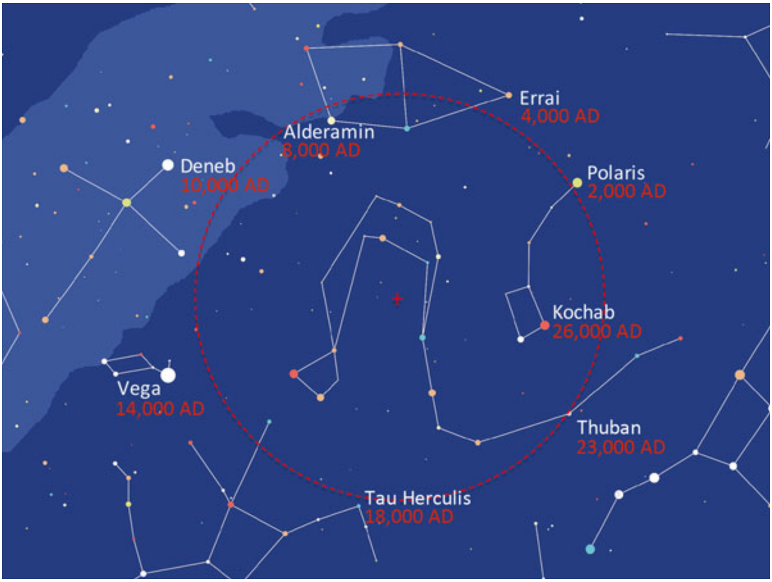

Fig. 11.5 Precession means that Errai will displace Polaris as the north star, followed by Alderamin, Deneb, Vega, Theban and Kochab as part of a counter-clockwise 26,000-year cycle. The year that each of these stars will next become the north star is shown in *red*. Credit: based on a chart on Wikipedia - Tau'olunga

The Giant Outliers

Although telescopes can glimpse stars the naked eye cannot, in the northwest sky this month there's a chance to look at the three most distant stars with just the naked eye.

Naked Eye Target: Deneb

At the back of Cygnus and the top of the sinking Summer Triangle, bright white Deneb (Chap. 6) is familiar to you, though until now we've not learned much about it. This +1.25 magnitude, white star is a mere 10 million years old and will go supernova (Chap. 2) within a few million more [Kaler 2015]. At least 1400 light years distant and over 100 times the size of the Sun, Deneb is 54,000 times more luminous.

However, nearby is another remote gem. This is an even larger orange supergiant that if put at the centre of our solar system would stretch to the distance of Saturn's orbit.

Naked Eye, Binocular and Telescope Target: The Garnet Star, Cepheus

A supergiant star around 2400 light years distant (Fig. 11.4), the Garnet Star (also called Mu Cephei) is the most orange star of all. There's an easy way of finding it, though you'll need binoculars to appreciate its orange color. Find Deneb in the western sky and head north about 12 degrees to Alderamin in Cepheus, at the bottom right-hand corner of the house shape. Now cross to the bottom left-hand corner of the house at Epsilon Cephei (see Fig. 11.4). Visualize a letter T that joins Epsilon Cephei and Alderamin at the top, and Deneb at the foot. At the intersection of the two lines is the Garnet Star. A +4 magnitude star, it's one of the few stars that it's worth getting a closer look at through a telescope just to appreciate its color.

As well as being one of the most distant naked eye stars, the Garnet Star is also one of the most luminous stars known at a staggering 600,000 times brighter than the Sun. It's also 1600 times larger. However, even that's topped by the equally distant—and possibly related—VV Cephei A in the centre of Cepheus (Fig. 11.4), a +4.9 magnitude star that is the biggest star we've come across this year.

The Most Distant Visible Star

Technically the most distant visible star is V762 Cas in the constellation of Cassiopeia. Though the eyesight of the beholder—as well as their darkness of the skies they're looking through—will make a big difference to whether or not you can see this distant and dim star.

Binocular Target: V762 Cas

Around 16,000 light-years away and at a visible magnitude is +5.8, you'll need super-dark skies to get eyes-on with this red supergiant. Binoculars will help. Find it almost exactly halfway between Segin in Cassiopeia (the left-hand point of Cassiopeia imagined as the letter W) and Errai at the apex of the roof of Cepheus (Fig. 11.4).

It may be the furthest star, but V762 Cas is not from the furthest object you can see with the naked eye. That distinction goes to either the Andromeda galaxy or the Triangulum galaxy (Chap. 9), which are a whopping 2.5 million and 3 million light years away, respectively.

The Fifth Planet

There are few greater sights than Jupiter and its four bright Galilean Moons. You've probably already seen them in a pair of binoculars (Chap. 4), but now it's time to get a close-up.

Jupiter orbits the Sun every 12 years, so although it does dip into the lowest part of the ecliptic (which is tricky to see from the northern hemisphere), it's most high in the sky and easy to see for months on end each year. By now you'll probably know exactly where Jupiter is, having tracked the progress of this, one of the brightest objects of all, across the night sky since January. If you don't, use a monthly updated star-chart or a phone app to check on its specific position, because it won't appear on a planisphere.

Telescope Target: Jupiter and the Galilean Moons

First, find Jupiter with binoculars, then point your red dot finder or finder-scope at it, and finally look through your telescope's eyepiece. Jupiter should look exceptionally bright, and yellow, while at least three of the four Galilean moons should be easily visible, and lined-up either side of the planet. Focus your telescope until these tiny dots of light around the gas giant look sharp. With patience, through a 4-inch. telescope it's possible to see three distinct equatorial bands on Jupiter. Those with large telescopes beyond about 10-inches will see perhaps five of those bands. Like all of the planets, Jupiter is best viewed when high above the horizon.

The Galilean Moons

Jupiter's Galilean moons are a superb sight in a telescope. They're called Io, Europa, Ganymede and Callisto, from closest to furthest from the planet. There are other moons here—60 others, in fact—but these four biggest moons are special indeed. As well as being discovered by Galileo Galilei in 1610 as the first objects to orbit another planet (and thus blowing wide-open the subject of astronomy) they're buzzing with exciting features and grand possibilities.

Io

The most geologically active place in the solar system, Io has mountains higher then Mount Everest and volcanic plumes that spew sulphur 300 miles up. This intense activity means that Io is the only object we've ever observed that doesn't have impact craters.

Europa

Roughly the size of our Moon, Europa is thought to have a liquid water ocean below its thick icy crust, and—uniquely—plate tectonics similar to that found on Earth. In December 2013, the Hubble Space Telescope detected water vapor above its south pole, and it's suspected that it hosts more water than on Earth. Should we send a probe? NASA thinks so, and wants help with planning a low-budget mission to reach Europa. Since it's probably had its ocean for millions of years, Europe is the favorite for extra-terrestrial life.

Ganymede

In your telescope Ganymede will look the brightest of all of Jupiter's moons. Bigger than Mercury and Pluto, and three-quarters the size of Mars [NASA 2015], Ganymede has its own magnetic field—and thus hosts auroral displays, known to us on Earth as the Northern or Southern Lights (Chap. 14). In studying those lights in 2015, the Hubble Space Telescope found evidence of an ocean of water beneath its icy crust. In 2030, the European Space Agency's JUICE (JUpiter ICy moons Explorer) probe will arrive to take a closer look (as well as at Europa and Callisto).

Callisto

In a telescope, Callisto is the furthest and dimmest moon. A fraction smaller than Mercury, Callisto is the most cratered celestial body ever studied. It's also suspected to have an underground liquid ocean, and because it's much further from Jupiter, it has far less radiation than Europa; a trip here might prove much easier for humans.

Jupiter's Surface

Those with a high power telescope should be able to make some of the key features in the Jovian atmosphere, but even with a 4-inch telescope you should be able to discern three or four distinct belts (Fig. 11.6). If you're lucky (with both the size of your telescope and the timing), the famous

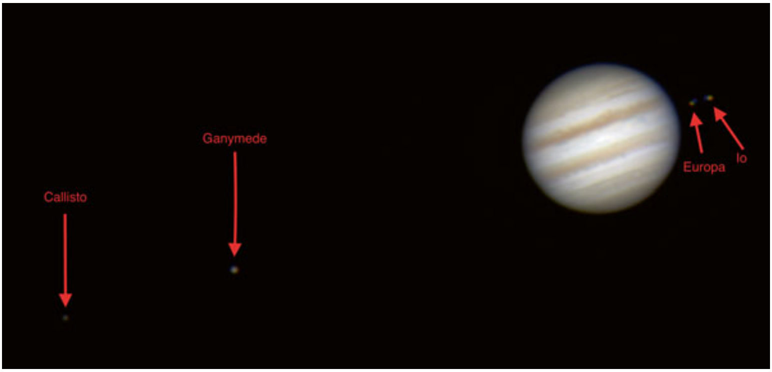

Fig. 11.6 Jupiter with all four of the Galilean moons visible. Credit: Massey/Neugent/Lowell Obs./NSF

Great Red Spot could be within your reach. However, most of us will get something much more basic, but no less stunning; a super-bright planet that moves quickly through the field of view. Unless you've got a tracking telescope, you'll have to adjust it often.

In comparison to the enormous 'hot Jupiters' astronomers have found orbiting other Milky Way stars, our own Jupiter is a 'cold Jupiter'. Around 5.2 AU or 779 million km from the Sun, Jupiter is made of hydrogen and helium—as stars are—but it's far too small to be considered a failed star.

Aside from the Sun, Jupiter is our solar system's linchpin; its gravity destroys asteroids, captures comets, and affects the orbits of everything in the solar system. Its exceptionally powerful gravitational pull is also why is has over 64 moons—those four you've just seen are only the largest. The fact that we have a planet as big as Jupiter so far from our star also appears to be pretty rare.

Disappearing Moons

On their journey around Jupiter, the moons cross in front of or behind Jupiter, or pass through its shadow, and thus will be hidden from sight, so don't be surprised if you can see only three of the moons. Occasionally all

of the moons are invisible, but that's very rare. Jovian moon-watching is a definite hobby; charts are published in monthly astronomy magazines that show you exactly what time to look for a transit of a moon across the face of Jupiter—an event that also causes a dark shadow to appear on the planet's surface—though you'll need a 16-inch telescope to see that kind of detail. It's much easier to look for all four moons lining up on one side, which happens relatively frequently.

The Grand Tack Model

The search for exoplanets (Chap. 8) is something of a gold-rush in astronomy, and with 300 billion stars to search around, there is plenty of work to do. However, what astronomers keep finding is hot Jupiters orbiting close to their star, which we don't find in our solar system. In such systems, small, warm, rocky worlds like our own could not exist because the gravitational force caused by planets as big as Jupiter would clear the area of smaller worlds.

The Grand Tack theory [Walsh et al 2011] says that Jupiter and Saturn likely formed much closer to the Sun, but their gravitational interaction drove both outwards (they 'tacked', like a yacht), creating space for Mercury, Venus, Earth and Mars to form. If hot Jupiters near stars are the norm, Earth-like planets don't generally form, which could make Earth—and life—if not unique, then exceptionally rare.

Using a Barlow Lens

There is an easy way to increase the magnification of your telescope. Most starter telescopes come with a couple of eyepieces, a low-power and a high-power; the first is useful for a reasonably wide-angle view that's nice and bright, while the second is for taking a closer look but it's somewhat dimmer. It's a trade-off, but if you're happy to push that trade-off to extremes without having to purchase additional eyepieces, a Barlow lens can help.

Power Play

Usually an additional purchase, but sometimes included with telescopes, a Barlow lens boosts the power of an eyepiece, typically doubling it. If you have eyepieces with focal lengths of 25 mm and 10 mm, a 2× Barlow lens placed between the eyepiece and a telescope's focuser effectively doubles the magnification, giving you the equivalent of 12.5 mm and 5 mm eyepieces (Fig. 11.7).

If you have a 4-inch/102 mm telescope with a 800 mm focal length, a 2× Barlow lens will push your 25 mm from 32× to 64× magnification. Your 9 mm eyepiece's magnification will grow from 89× to 178×. On a 10-inch scope with a focal length of 1200 mm and both 25 mm and 10 mm eyepieces, a 2× Barlow lens will get you from 48× to 96×, and from 120× to a whopping 240×. It's also possible to buy a 3× Barlow lens.

Fig. 11.7 A 2× Barlow lens is a good value way of increasing magnification without having to buy new eyepieces, particularly when planet-spotting. © Jamie Carter

Double Trouble

It's the 5 mm that will likely tempt you most, though there are caveats to using a Barlow lens. While planets and the Moon are ripe for extra magnification, the Andromeda galaxy (Chap. 10) and other faint objects are not.

The images a Barlow lens produces is significantly dimmer and more difficult to focus than unadorned eyepieces normally manage. Also, don't expect Jupiter to suddenly fill your telescope's field of view, or for the Great Red Spot on Jupiter's surface to come into sharp focus.

Use a low-power eyepiece to find your target, then gradually zoom-in, finally placing a 2× Barlow lens beneath a high-power eyepiece. If you're looking at a planet or the Moon, your target can easily race out of your field of view while you swap between eyepieces, which is why a motorized telescope that can track objects is valuable. Just remember that more magnification isn't necessarily what every object in the night sky either requires or can stand.

Telescope Target: Phases of Mercury

If you can catch Mercury (Chap. 7) high above the horizon after sunset, you've got it at its greatest western elongation—the furthest it appears to be from the Sun as viewed from Earth. When at its greatest eastern elongation it's visible before sunrise. Either elongation is a great time to look at it with the naked eye, but a poor time to put it in a telescope; there's little to see. However, there is one brief period when it's a challenging, but brilliant sight in a telescope. Mercury has crescent phases like Venus and the Moon, but they're only visible for a few days as Mercury is getting closer to the Sun (and so harder for stargazers to see).

Timing is everything for this small target—as is good seeing (Chap. 10), which is a big problem this close to the horizon—but you should be able to see a half-lit gibbous Mercury wane to a crescent over about a week. It's a trade-off; as it sinks the crescent gets thinner, so more interesting to look at, but it also gets harder to see. A 4-inch telescope and a high-power

eyepiece should do the trick, though you have to time this one right. Mercury reaches its greatest elongation three times per year, or every four months, though it's visible for a few weeks either side. Check an astronomical calendar and make a note in your diary.

Telescope Target: The Moon Through a Barlow Lens

Though you may find that the standard high-power eyepiece supplied with you telescope offers you as much of a close-up as you want or need, a Barlow lens can help you zoom in on some of the Moon's craters and rays (Chap. 10).

The Moon in Close-Up

Look at the Moon in low power, first through binoculars and then through a 25 mm or so eyepiece on a 4-inch telescope. With a good map, you'll be able to pick-out some fine detail. In the two weeks between New Moon this month or next, have a look for these features (below), and try taking a closer look using a high-power eyepiece, such as 9 mm or 10 mm. However, do take care; not only will the Moon race out your field of view quicker, but using a higher magnification will also reduce the surface brightness.

When to Look at Craters

Craters (Fig. 11.8) are best seen when they are close to the terminator line between New Moon and Full Moon, when they throw hugely impressive shadows. If you want to locate them all at once, a rising Full Moon is a good time to do this because the entire surface is visible. However, some of the features are harder to spot when in the full glare of the Sun.

These features will look just as good in the second-half of the Moon's orbit when the terminator returns, though only night owls will see them.

The waning gibbous Moon can often be seen in the west until lunchtime, so Moon-gazing during the day is possible, and a great way of practicing your lunar geography.

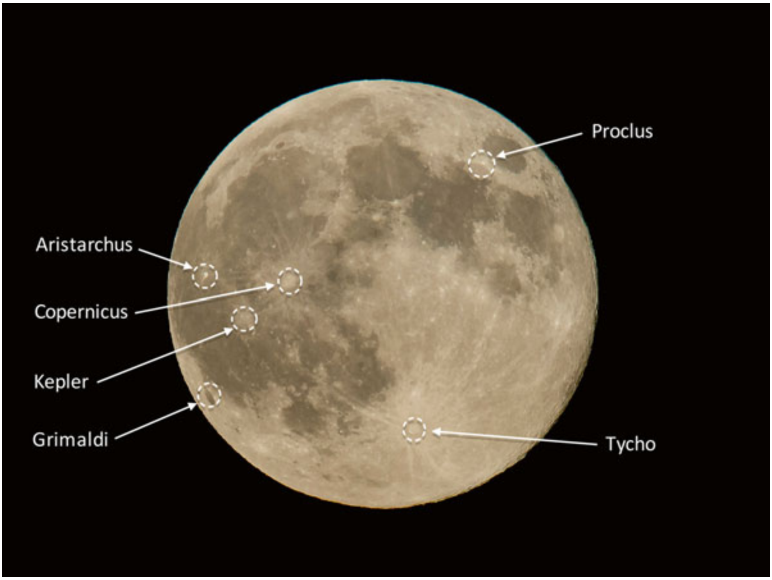

Fig. 11.8 Major craters on the surface of the Moon. Credit: NASA/Bill Ingalls

Binocular and Telescope Target: Tycho Crater and Rays, the Moon

At the center of the southern polar region of the Moon, and best seen around First Quarter, Tycho is one of our satellite's most famous craters. This spectacular crater has debris spraying in all directions.

Binocular and Telescope Target: Copernicus Crater and Rays, the Moon

An impact crater bigger than Tycho and best seen at roughly the same time, Copernicus in the eastern Ocean of Storms, just north-west of the center, is bright and has rays of debris spreading in all directions.

Binocular and Telescope Target: Kepler Crater and Rays, the Moon

Keep going to the left from Copernicus and you'll get to Kepler, another lunar impact crater, and around 32 km wide. It's best viewed in the few days before or after Full Moon.

Binocular and Telescope Target: Grimaldi Crater, the Moon

On the lower left-hand side of the Moon, as viewed from Earth, the 220 km-wide basin of Grimaldi is a great sight to find during a Full Moon. Since it's only possible to view it at Full Moon when the lunar disc is bright, Grimaldi is best seen at Moon-rise (Chap. 8). A small dark patch in otherwise pale surroundings, once seen you'll never fail to notice it again—it's a Moon-gazing classic.

Binocular and Telescope Target: Proclus

In the wonderfully named Sea of Crises—in the top-right of the Moon—is tiny Proclus, a pentagon-shaped, low angle impact crater where you can see rays of debris around two-thirds of it. Find it in the gap between the Sea of Crises and the Sea of Tranquility.

Binocular and Telescope Target: Aristarchus

One of the brightest craters of all and impossible to miss once you've seen it, Aristarchus is on the far left-hand side of the Moon, as viewed from the northern hemisphere, just above the Ocean of Storms. Catch Aristarchus a few days either side of Full Moon to see it in the shadow of the terminator.

Fig. 11.9 A Moon filter can reduce the glare of the Moon, but so can wearing shades. © Jamie Carter

Using a Moon Filter … or Shades

A bright Moon is hard to look at, but it is possible to buy a relatively low-cost Moon filter for telescope eyepieces, which significantly reduce the glare (Fig. 11.9). A blue filter will do much the same job. However, if you don't want to invest in an accessory that you may not use much, just don a pair of shades and look through your telescope's eyepiece as normal. You may feel a little strange wearing shades at night, but, who's going to see them?

References

Dunlop, Storm. Night Sky: Get to Know the Natural World. HarperCollins, London. 2004.

Kaler, Jim. 2015. Stars. [ONLINE] Available at: http://stars.astro.illinois.edu/sow/sowlist.html. [Accessed 01 June 15.]

NASA. Ganymede: Overview. [ONLINE] Available at: https://solarsystem.nasa.gov [Accessed 02 June 15]. 2015.

Stoyan, Ronald., Binnewies, Stefan & Friedrich, Susanne. Atlas of the Messier Objects: Highlights of the Deep Sky. Cambridge University, New York, Melbourne, Madrid, Cape Town, Singapore, Sao Paulo, Delhi. 2008.

Walsh K.J., Morbidelli A., Raymond S.N., O'Brien D.P. & Mandell A.M. Populating the asteroid belt from two parent source regions due to the migration of giant planets--"The Grand Tack". Nature, 475. 2011.

CHAPTER 12

DECEMBER: ORBIT COMPLETE

The Stars of December

With Orion in the night sky, there is only one sensible thing to do with your telescope; point is straight at the Orion Nebula. This birthplace of stars in our neighborhood is much-loved by all stargazers, but particularly adored by owners of telescopes. Since you're likely to be around family and friends this month, there is a brief Grand Tour to share with them over the holiday season, and also with anyone who's been gifted a telescope for Christmas. Bigger yet still inexpensive binoculars can be just as rewarding as a telescope, and this month we'll consider some of the finest sights that benefit from extra magnification for two eyes.

Besides the chance to take a closer look at some of the gems we examined 11 months ago, this month includes advice on how to stargaze from 30,000 ft and when to witness the most powerful meteor shower of all. Can you hack the cold and get the reward of up to 120 bright shooting stars per hour? It's a freezing yet fitting way to end your first orbit as a stargazer.

The Return of Orion

After six months away from the night sky, Orion climbs in the east this month, with the three stars of Orion's Belt making it instantly recognizable. Arm yourself with binoculars and a telescope, if you have one; we have many wonders to find.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_12

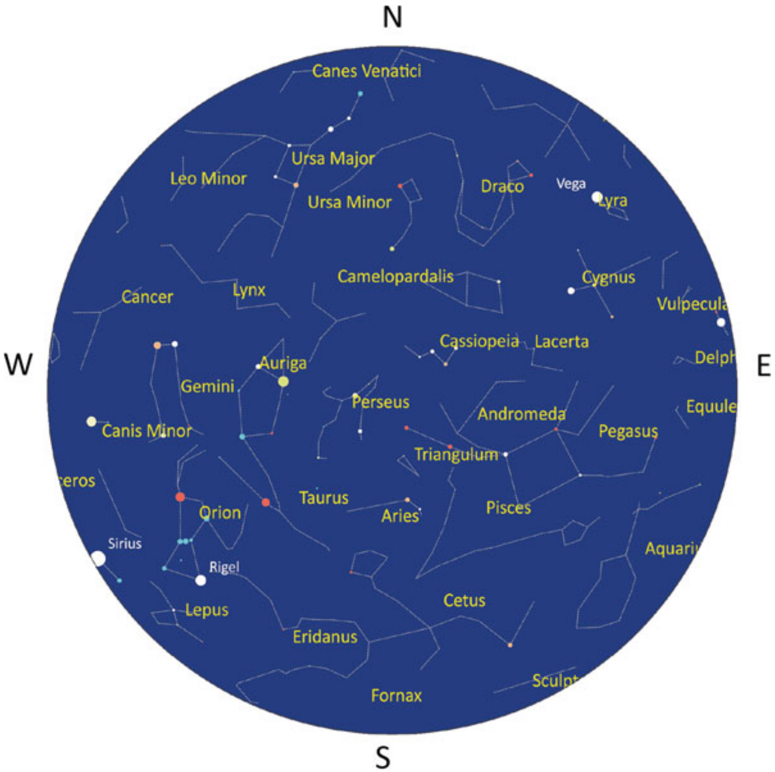

Fig. 12.1 Star-chart for December 1 at 10 pm

Telescope Target: Orion Nebula, M42

To the naked eye it looks like a fuzzy star in the middle of Orion's Sword, and in binoculars a cloudy patch of almost unbelievable brightness (Chap. 2). In a telescope, the Orion Nebula is a lot more subtle. Look into this stellar nursery with almost any telescope and you'll see the Trapezium. With about 100× magnification you should be able to resolve three or possibly four stars. That becomes easier with larger telescopes; with a 10-inch telescope you'll see the defined shape of M42 that will likely be familiar to you from Hubble's dramatic photographs (Fig. 12.2).

Fig. 12.2 The Orion Nebula, as photographed by the Hubble Space Telescope in 2006. Credit: NASA, ESA, M. Robberto (Space Telescope Science Institute/ESA) and the Hubble Space Telescope Orion Treasury Project Team

Use averted gaze and you'll begin to see the luminosity that was so obvious in binoculars; that light is gas and dust being illuminated by stars within it. Eventually, M42 will become a star cluster like the Pleiades, the Hyades and the Beehive.

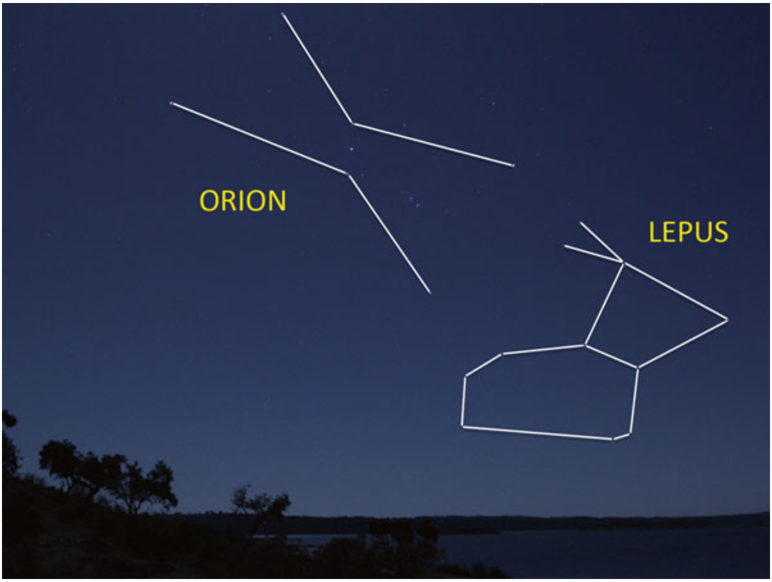

Fig. 12.3 The constellation of Orion rising in December, with Lepus below. © Jamie Carter

Naked Eye Constellation: Lepus

It's great to see Orion back in the night skies, but there are plenty more constellations to find even in this well-known region of the night sky. So often ignored and looked right past, this animal shape will be visible late at night towards the end of the month, as Orion rises higher in the sky. Look immediately under Orion, in particular Rigel, keeping rising Sirius on the left, and you'll see a small and the rather obvious shape of a rabbit.

Telescope Target: Struve 747, Double Star in Orion's Sword

M42 gets all the love, but there's plenty more to look at nearby (Fig. 12.4). Just below it is bright Nair al Saif, and just south-west of that is Struve 747, a bright star that's simple to split into two with any telescope. It's a runaway star from M42.

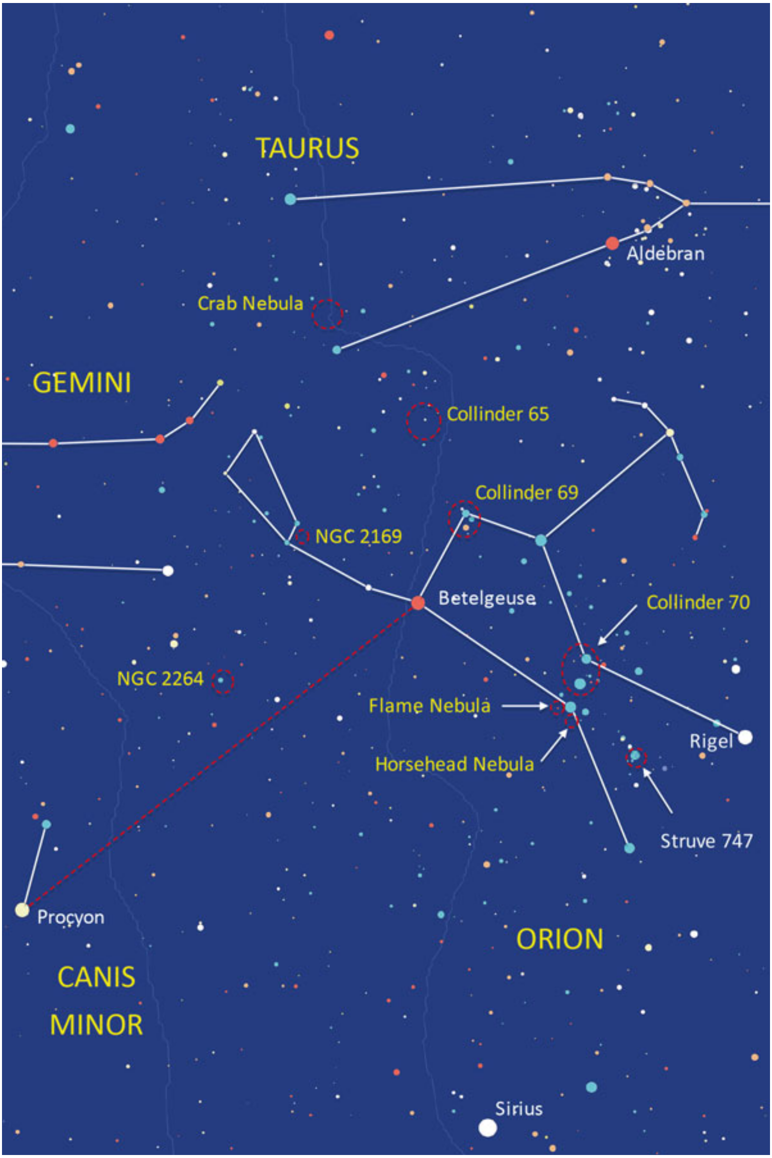

Fig. 12.4 Seasonal favorites this month include the Struve 747 double star and three open clusters; Collinder 65, Collinder 70 and NGC 2264, the Christmas Tree cluster. The positions of the Horsehead, Flame and Crab nebulas are also indicated

Binocular Target: Collinder 70 Open Cluster, Orion

Almost everyone looks straight past this asterism, but once seen it's impossible to forget. Put Alnilam, at the center of Orion's Belt, in your field of view, then scan slightly to the right to get Mintaka in, too (Fig. 12.4). Between those two Belt stars is a winding stream of about 14 stars that make the letter 'S'. At around 1300 light year distant, Alnilam is part of the Collinder 70 open cluster, whereas Mintaka is in front, and much closer to the solar system. A blue supergiant, four million year old Alnilam is on course to become a red supergiant, much like Betelgeuse only far brighter (Kaler 2015).

Binocular Target: The Triangle, Collinder 65 Open Cluster

Yet another triangle! Much smaller than most of the big seasonal three-pointers, this one is found within a cluster of stars about 1900 light years distant, it can be seen above Orion. Just form an arrowhead from Betelgeuse, Bellatrix and Collinder 69 (a loose star cluster around Meissa, which is a double star) at the head of Orion (Fig. 12.4); it points to Collinder 65. You should see around 50 stars fill the field of view in your binoculars (Tonkin 2014), with a small triangle of stars in the lower part of the cluster.

Binocular Target: Christmas Tree Cluster, NGC 2264

Does it look like a Christmas Tree? I'm not convinced, but it's bright and well-placed in December. Draw an imaginary line between Betelgeuse in Orion and Procyon in Canis Minor across a seemingly empty patch of sky (Fig. 12.4). Above the half-way point you should be able to see a wedge-shaped open cluster of around 80 stars (Tonkin 2014). About 2600 light years distant, it's actually in the constellation of Monoceros, which is a target for next year, perhaps when you're under very dark skies. Note how faint the stars are in this area of the sky; it's thought to be because of a large amount of interstellar dust (Tonkin 2015).

Hubble's Greatest Images Revealed

Two of the Hubble Space Telescope's most well known photographs were taken of the Horsehead Nebula and the Crab Nebula (Fig. 12.5), both near the constellation of Orion.

Minds's Eye Targets: Hubble's Most Famous Images

It's Alnitak, the unassuming star on the left of Orion's Belt that gets most of the attention. The Horsehead Nebula (Barnard 33) is positioned below it (and the lesser-known Flame Nebula is on the star's left-hand side) while the Crab Nebula (M1), a supernova remnant, is above Orion's head, officially in Taurus (Fig. 12.4). While it's possible to glimpse the +8.4 magnitude Crab Nebula with a small telescope, it's hugely sensitive to light pollution and can be a frustrating (and not particularly rewarding) hunt. It's best left for a star party or observatory trip where you might get a chance to use a bigger telescope. At +10 magnitudes, the Horsehead Nebula and Flame Nebula require a 12-inch or larger telescope at least. Of Hubble's other legendary images (Fig. 12.5), the Pillars of Creation is a dust cloud in the Eagle Nebula (M16) near the constellation Sagittarius (Chap. 7).

Bigger Binoculars

While a pair of 10 × 42 or 10 × 50 binoculars are great all-rounders and perfect for travel, if you're a big fan of using two eyes over one, some more magnification is tempting. As you up the magnification, the aperture has to rise, too, which means a bigger product that's neither as portable (big binoculars no longer fit easily into carry-on luggage, for example) nor as easy to hold steady; as a rule of thumb, anything larger than 10 × 50 should be mounted on a tripod. Common specifications here include 15 × 70, 20 × 80 and 25 × 100 (Chap. 4), all of which will provide a tighter field of view and more of a close-up. Instead of concentrating on the center of the field of view in a pair of 10 × 42 or 10 × 50 binoculars, that same object viewed through a pair of big binoculars suddenly fills the field of view and becomes easier to study.

Fig. 12.5 Hubble's most famous photos, the Horsehead Nebula (*top*), Crab Nebula (*lower right*) and the Pillars of Creation (*lower left*). Credits: Horsehead Nebula—NASA, ESA & Hubble Heritage Team (AURA/STScI), Crab Nebula—NASA/ESA/J. Hester and A. Loll (Arizona State Univ.) and Pillars of Creation—NASA, ESA/Hubble and the Hubble Heritage Team

Fig. 12.6 Canon image stabilized binoculars are expensive, but offer a very steady view of the stars. Credit: Canon

Mounting Binoculars

Since the unsteady view you get through your current binoculars will only get worse if you use a higher magnification, big binoculars are best used mounted on a tripod. Various brackets are available, but try to buy a pair of big binoculars that has a screw thread for a tripod. Quicker to set-up than a telescope, and more portable and cheaper, a pair of mounted binoculars is much favored by experienced stargazers (Fig. 12.6).

The Alternative: Image Stabilization

Canon is now selling binoculars that use unique Vari-Angle Prism (VAP) image stabilization sensors to get rid of any judder in the image that comes

from hand-holding them. Even just trying-out a pair and comparing them to a normal pair of binoculars will make you realize how unsteady you are! There are only two downsides to this clever system; it's battery driven, which makes the binoculars heavier than most, and they cost an awful lot of money (a pair of Canon 10×42 L IS WP binoculars were going for US$1250 at the time of writing). If you can afford to spend that much, I highly recommend them; as well as getting a steadier view of clusters, it's much easier to split double stars. Mostly they come in smaller sizes, though the largest size available is 15×50, which is a big (and heavy) pair of binoculars. All are waterproof, so dewfall is not a problem if you stay out late at night.

Big Binocular Targets: Orion Nebula, Pleiades, Double Cluster and Beehive Cluster

Big binoculars are perfect for fans of star clusters because some of the closest and biggest tend to fill the field of view and look spectacular. If you've binoculars rated at 15×70 or similar, prominent clusters such as the Pleiades, the Double Cluster and the Beehive Cluster (Chap. 4) look absolutely stunning, though only if you can keep your binoculars still.

The Orion Nebula (see above) to the south also looks terrific in big binoculars. If you can keep them steady, you should be able to resolve four stars in the Trapezium within the Orion Nebula—a stunning sight!

Big Binocular Target: The 37 Cluster, NGC 2169

Here's another target that is only properly visible in a pair of big 15×70 binoculars. Close to the fabulous M35 in Gemini, this unusual asterism is a small open cluster of about 30 stars that looks like a representation of the number 37. It's easy to find; visualize a line from Alnitak on the left-hand side of Orion's Belt up to Betelgeuse, and keep going up for the same distance again (Fig. 12.4). It's roughly an outstretched fist above Betelgeuse. You'll come to two bright stars; just below them is NGC 2169, an oval of about 15 stars in the shape of a '3' or a 'W' on its side (it also resembles an

elongated Big Dipper) and a faint '7' below it. These stars are about 3600 light years away. It's just possible to find the '3' with 10×50 binoculars, though only if you've visited NGC 2169 before.

The Twins

Its position close to Orion means Gemini (Chap. 3) is a constellation that's often ignored. Not only is its major open cluster, M35, worth a second look as Gemini rises from the east this month, but one of its brightest stars is masquerading not as a binary system, but something even more spectacular and strange.

Big Binocular Target: M35 Open Cluster, Gemini

Although you can see this busy open cluster under a dark, transparent sky with both the naked eye and a pair of 10×50 binoculars, urban stargazers will have the best chance with bigger binoculars. Initially merely a small misty patch near Tejat Posterior, the back foot of Castor, in big binoculars you should be able to see some prominent stars against a background of about 100 (Fig. 12.7). M35 is about 2800 light years distant and positioned in front of the Milky Way.

Telescope Target: M35 Open Cluster, Gemini

Put a minimum 4-inch telescope with a low-power eyepiece (to maximize brightness) on M35 and this open cluster suddenly comes to life. Be patient; around 30 stars are visible at first glance, but a web of many more appears after a minute or two's observing. It's a maze of shapes in there; you'll see all kinds of crowns, curves and coat hangers if you look carefully.

Telescope Target: Castor, the Double-Double-Double

We've seen binary star systems, and even triples, but whoever heard of sextuple star system? Rated as the 23rd brightest star in the sky, to naked

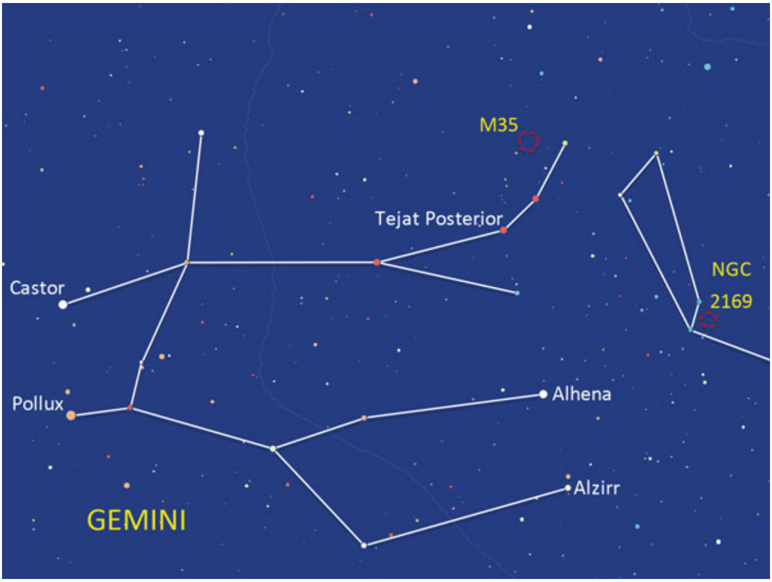

Fig. 12.7 Castor, the double-double-double star in our midst, with M35 and NGC 2169 close by in Orion

eye stargazers Castor (Fig. 12.7) plays second fiddle to the constellation's brightest star, Pollux. However, Castor—only around 50 light years distant—is actually three pairs of binary stars. Point any size of telescope using a high-power eyepiece at Castor and you can split it into its two bright, white stars, Castor A and Castor B, which orbit a common point. In a 6-inch or bigger telescope you might even see a third, Castor C, close-by, though it's very faint. A and B orbit each other every 445 years, while C takes 1400 years to make the journey around them. Although stargazers can see no more detail, each of these three stars is actually a binary system itself, making a total of six stars all gravitationally-bound to each other.

The Phases of Venus

There are three celestial bodies that stargazers can see as crescents; the Moon, Mercury (Chap. 11) and Venus.

When it's at its highest in the evening sky, and so furthest from the Sun from our perspective—its maximum elongation—Venus is a dazzling naked eye sight, but in a telescope it's bright, white and featureless. However, when it's between Earth and the Sun—something called inferior conjunction (the New Moon is said to be in a conjunction with the Sun)—it's possible to see a crescent Venus (Fig. 7.7), though only in close-up through a telescope.

Telescope Target: A Crescent Venus

Though by definition you have to catch it in twilight as the planet sinks from view, and so through the thickest part of Earth's atmosphere, a crescent Venus is a fine sight, and the slighter it is, the easier it is to notice.

We can never see Mars, Jupiter or Saturn—the superior or outer planets—as a crescent because they never get between us and the Sun. Though they may appear to be very close to the Sun, and so become evening or morning objects only, they're merely on the far side of the Sun to Earth, and so are still receiving the full glare of the Sun. To get a view of a crescent Jupiter, you'd have to be on Saturn, a crescent Mars would only be visible from Jupiter or Saturn, and a crescent Earth would only be visible from Mars, Jupiter or Saturn … or the Moon, as demonstrated by the Apollo astronauts.

Two Clusters in Cassiopeia

Since it lays across the Milky Way, Cassiopeia a great place to sweep binoculars. It's rich in open clusters, though they often get missed. High in the northern sky this month hanging as an ever-present M-shape, this famous constellation can play host to hours of cluster counting, but here's two easy to find examples to get you started.

Binocular and Telescope Target: Open Cluster M52

By now you'll appreciate a good misty patch, and that's what this compact cluster looks like in binoculars. It would be almost impossible to find if it wasn't for some usefully placed stars that giveaway its general location.

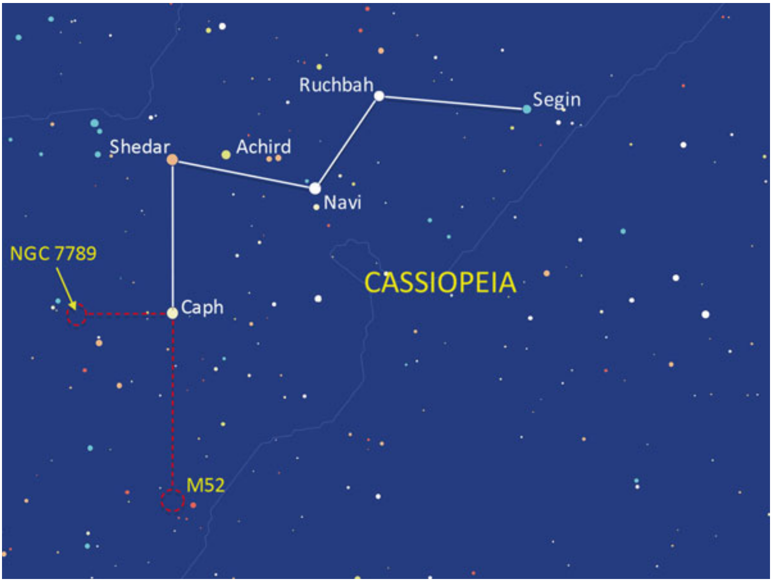

Fig. 12.8 Two open clusters around Cassiopeia, M52 and NGC 7789, and Achird, a G-type *yellow dwarf star* similar to the Sun

Visualize a line from Shedar to Caph in Cassiopeia, and keep going for the same distance again (Fig. 12.8). In both binoculars and a small telescope you should notice a yellow star on the western side that contrasts with the blue-white the others (Tonkin 2014) in a dense but hazy field of view. Larger telescopes will reveal around 30 stars.

Big Binoculars and Telescope Target: Open Cluster NGC 7789

Some decent magnification is needed to see individual stars in NGC 7789, but it's worth finding—near to M52 (Fig. 12.8)—if only for its unusual status as a billion-year old cluster (Consolmagno and Davis 2011) where most of the stars are red supergiants. Teasing-out individual stars takes a large telescope using a high power eyepiece.

Sun-Like Stars

Although most of the stars easily visible in the night sky are bigger and brighter than our Sun (Chap. 8), there are some that are much the same. One of the best examples of a G-type star that's almost identical to the Sun is Achird in Cassiopeia (Fig. 12.8). Two other examples of G-type yellow dwarf stars include the closest star system to us, Alpha Centauri (Chap. 13) at 4.3 light years and 51 Pegasi (Chap. 10) at around 51 light years.

Naked Eye and Telescope Target: Achird, Cassiopeia

At a magnitude of +3.4, Achird is easy to spot in the constellation of Cassiopeia, next to the brightest star, Shedar (Fig. 12.8). It's a mere 19 light years distant. Through even a small telescope, a pair are easily resolvable; a brighter yellow star and a fainter orange star make an intense contrast (Kaler 2015). While the yellow star is Sun-like, the orange star is half the radius of the Sun.

The smaller star in this binary pair has an elliptical orbit that is causing them to separate, so splitting them will get easier with every passing year for the next few decades (Mollise 2006). Unlike 51 Pegasi, no planets have been found around Achird.

The Winter Circle Revisited

Late this month sees the return of the vast Winter Circle asterism (Chap. 2), which is rising in the east by midnight. Back in February we used it to see depth in the night sky, considering each of the seven member stars' distance from us in light years (Table 2.2). Rigel seemed the odd one out, being around 800 light years from us while the six others are all less than 65 light years.

However, celestial geography is as much about time as it is about distance. Look at this list of the Winter Circle stars again, this time with their ball-

Table 12.1

Star/Age
Sirius in Canis Major (238 million years)[a]
Rigel in Orion (10 million years)[b]
Aldebaran in Taurus (3.2 billion years)[b]
Capella in Auriga (500 million years old)[c]
Castor and Pollux in Gemini (370 million years and 700 million years)[d]
Procyon in Canis Minor (1.7 billion years)[e]

[a] Holberg (2007)
[b] Kaler (2013)
[c] Kaler (2009)
[d] Schaaf (2008) and SolStation (2011)
[e] Schaaf (2008)

park ages beside them, and you'll take a fresh new look at some of the stars you thought you knew so well. As you can see, the odd ones out this time are clearly Aldebaran and Procyon, both of which are vastly older than the others in the Winter Circle. However, it also underlines exactly how old our Sun is; at 4.5 billion years, it's been around far longer than most of the visible stars in the night sky.

The Geminids Meteor Shower

Clear your diary for the second-best meteor shower of the year, the Geminids, which can produce over 100 shooting stars per hour. It's 10 days long, peaking in mid-December, but don't make the mistake of finding out the evening it's expected to peak and only going outside then. At this time of year the chances of clear skies diminish, so just try to get outside for 30 minutes (if it's really cold) each time it's clear during the Geminids to maximize your chances of fireballs.

Whether this strong meteor shower lives up to its billing will depend on three things; clear skies, where the Moon is in its monthly cycle, and your own ability to stay outside in the cold. If you get a clear sky and absent Moon, it's possible to see multiple shooting stars in just the first few minutes.

The Winter Solstice and Beyond

With the Sun in Ophiuchus as it hangs over the Tropic of Capricorn and the days as short as they get in the northern hemisphere, sign-off your first year as a stargazer with something special. Get up well before dawn on December 21–22 (the actual date can vary each year) to celebrate the winter solstice up close and personal with some extra-special stargazing. While the Big Dipper reigns supreme above your head, you'll see some old friends rising in the east; Deneb and Vega at the top of the Summer Triangle, Hercules and Corona Borealis, Bootes and Leo. Look the other way and you'll see Gemini and Orion setting in the west, taking the Orion Arm of the Milky Way with it. It's not a strong meteor shower, but the Ursids will likely be peaking, too, sending a few sparks from above as you stand in (now official) winter and glimpse the stars of spring.

Stargazing on the Fly

For many people, the onset of the holiday season means a night-flight home or away to spend time with loved ones. Unless you're headed to the equator or even further south, the stargazing opportunities when you get there won't be much different. However, you've stumbled on a festive way to glimpse some of the stars only visible from southern latitudes. Next time you're flying in the northern hemisphere make sure you get a seat on the south-facing side of the plane. For instance, if you're flying from Washington D.C to San Francisco or from London to New York, book a window seat in advance on the left-hand side, and for the return journey, on the right-hand side. This way, the ecliptic—and so, the planets—will be in full view.

Naked Eye Activity: Stargazing at 30,000 ft

Far above the thickest part of Earth's atmosphere, the stars up here don't twinkle, they glare. Planets glisten in the clarity—it's a great time to spot Venus and Mercury just after a sunset—and if you're flying just before Christmas, keep an eye-out for a Geminids meteor. It's also possible to peek Canopus and Achernar (Chap. 13) below Sirius, usually only visible to those

on the equator, or in the southern hemisphere (though anyone in Florida and Texas can glimpse it from January-March).

However, if you're flying at high northern latitudes—perhaps in Alaska or Canada, to Europe or Scandinavia, or over Russia and Siberia on your way to the Far East—consider switching sides to swap stars for a possible glimpse of the Aurora Borealis or Northern Lights (Chap. 14).

That's a tough choice! Wherever you are, the Moon is often easily viewable from a plane, day or night, though it helps if it's near to the horizon where you can see it. This is where a good Moon phases app comes in, which you should look at either before you board, or before you check-in online (if you want to select your seat before you fly). Note what time the Moon will rise or set, and look out for it while everyone else watches bad movies.

High Altitude Observing

Tactics while on board the plane range from the obvious to the downright strange. It makes sense to sit away from the wing if you want to take photos (Northern Lights photos taken from planes can be stunning, though note that a DSLR and a slow shutter speed produces far better results than a smartphone). Either way, you'll get better results if you cover yourself, your camera and the window, with a blanket to stop reflections from screens and devices (Rao 2005). Prepare for questions from passengers and staff!

The Backyard Grand Tour

By now, word of your stargazing prowess will have spread, and if you're spending the holiday season with friends and family, it's a good chance to share your knowledge. So here are ten top sights and facts, all of which we've covered in the last year, and all of which are visible in December. Most are naked eye or binocular sights, but some are best seen in a telescope, which could be handy if a relative has received a telescope for Christmas and doesn't know what to point it at.

Show them and share them with anyone interested enough to follow you outside in to the backyard in likely freezing temperatures (Table 12.2).

Table 12.2 The Backyard Grand Tour

Top ten sights (all visible in December)		Best seen with…
The Pleiades or Seven Sisters	How many stars can everyone see in the Pleiades? Five is normal. This, our nearest star cluster, is just 440 light years away (Chap. 2), though the closest star we can see from above the equator is Sirius rising in the southeast, the brightest star, at just 8.6 light years	Binoculars
How to Find Polaris	Everyone knows the Big Dipper. Explain the 'spring up, fall down' mnemonic, and describe how the pointer stars always lead to Polaris (Chap. 1), which never appears to move because the Earth's rotational axis points straight at it	Naked eye
Double Star in the Big Dipper	Look again at the Big Dipper, and ask viewers to look carefully at the second star in from the end of the tail. Some will see two; Alcor and Mizar (Chap. 1), though Mizar is actually a sextuplet star system	Naked eye and binoculars
Planets and the Moon	These are obvious to point out, though whether Venus or Mars (Chap. 7), Jupiter and its moons (Chap. 4), Saturn (Chap. 9) or the Moon are going to be visible is something you'll know well in advance if you're stargazing regularly	Telescope
Orion's Belt	Rising in the south-east, possibly visible between trees and buildings, is one of the most recognizable asterisms of all. But Orion's Belt (Chap. 1) is merely a chance alignment; those three stars are not really side-by-side. The middle star is by far the largest, and over 1300 light years away from us, while the other two 800 and 900 light years respectively—so there is no Belt. Near the star on the left is the famous Horsehead Nebula, while winding between the middle and far-right star is an intriguing S-shape of stars	Naked eye and binoculars

(continued)

Table 12.2 (continued)

Top ten sights (all visible in December)		Best seen with…
Orion Nebula	If Orion is up and high enough in the night sky, the Orion Nebula (Chap. 2) is a no-brainer of a sight to share. It's the birthplace of stars in our region of the Milky Way, and two stars in the northern hemisphere sky appear to have come from here; AE Aurigae in Auriga and 53 Arietis in Aries	Binoculars
The Winter Circle	Bright star Sirius may be yet to rise, but the majority of this huge asterism (Chap. 2) can be pointed out. Start with Procyon and Rigel low in the east, finishing at Aldebaran	Naked eye
Orion Arm of the Milky Way	Explain that every star we can see in the sky is within the Milky Way (Chap. 2) alongside at least 100 billion others. Point out the Milky Way, even if it's not visible where you are; at this time of year it arcs from Vega in the west through Cassiopeia at the zenith and down through Capella due east. From Cassiopeia down is the Orion Arm that contains the solar system	Naked eye
Great Square of Pegasus	High in the south-western sky, this huge asterism (Chap. 9) is hard to forget once you've spotted it because (to the casual observer) it never looks upside-down. It also helps you find the next, and most stunning object	Naked eye
The Andromeda Galaxy	Finish on a high by pointing out our neighboring big galaxy (Chap. 10), which is bigger than the Milky Way and contains a trillion stars. Though far, far beyond the stars we can see, it's coming towards us at 250,000 miles per hour and will collide with the Milky Way in four billion years. The light from this misty patch has taken 2.5 million years to get here	Telescope

The Age of Apollo

Where did Neil Armstrong first step on the Moon? It's a common question that all stargazers should know the answer to, and a basic Moon-watching fact. Lesser-known, though increasingly just as big a milestone, is where man last walked on the Moon. If you're interested in exactly where all six Apollo missions landed, visit the excellent Google Moon website[1] or download Google Earth, which has a Moon mode (as well as Sky and Mars modes, too).

Naked Eye and Binocular Target: The First Man on the Moon: Tranquility Base

With even small telescopes it's possible to find the Moltke Crater just below the landing site of Apollo 11 astronauts Neil Armstrong and Buzz Aldrin, but that's probably overkill. The general area is easy to point out while looking at the Moon through binoculars or with the naked eye. Tranquility Base, as Armstrong declared it just after landing, and where he took his 'giant leap for mankind' on July 20, 1969, is on the lower-left-hand side of the Sea of Tranquility (Fig. 12.9).

Naked Eye and Binocular Target: The Last Man on the Moon: Taurus-Littrow Valley

The area where Apollo 17 astronauts Gene Cernan and Harrison H. Schmitt (who was actually a geologist) spent 72 hours in during December 1972, and even explored on a Moon-buggy, is on the lower right-hand side of the Sea of Serenity (Fig. 12.9). Cernan took man's last step from the surface of the Moon on December 14, 1972. Apollo 17 is as big a landmark as Apollo 11; as the passage of over 40 years atests, men on the Moon is not likely to happen again anytime soon. Apollo 17 was also the last time man left a low-Earth orbit.

[1] www.google.co.uk/moon

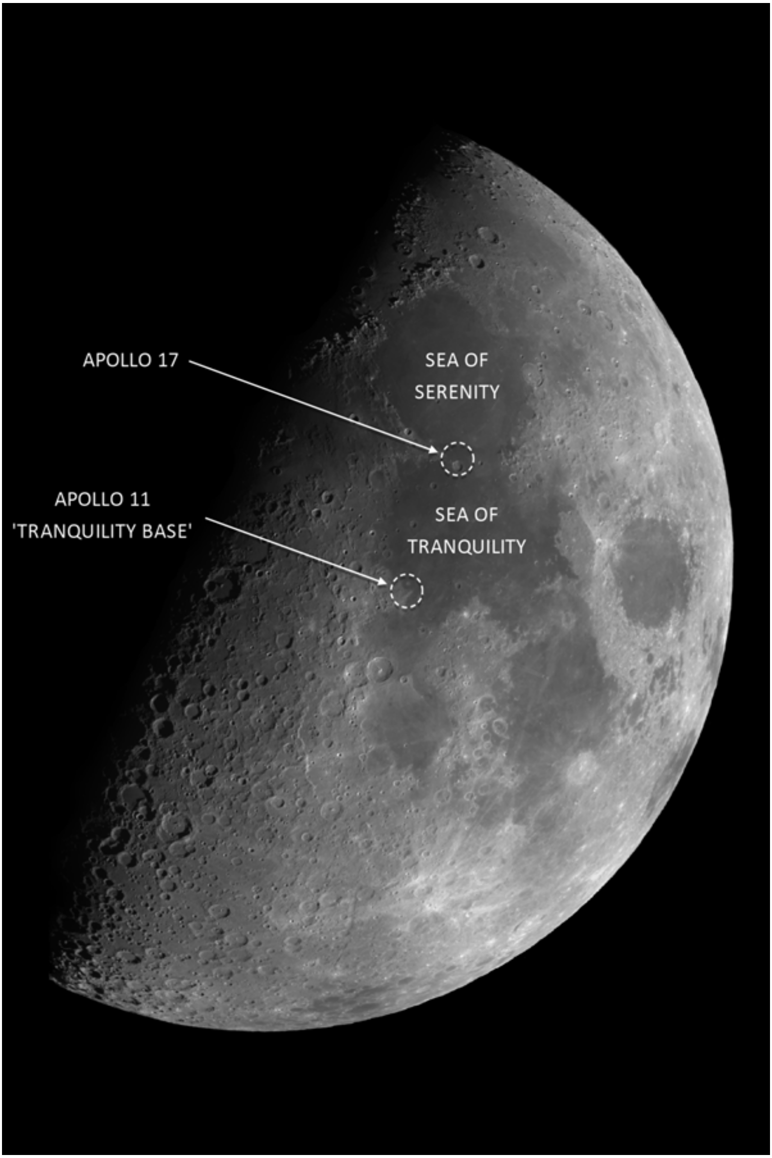

Fig 12.9 The landing sites for the first and last Moon landings, Apollo 11 & Apollo 17. Credit: Massey/Neugent/Levine/Lowell Observatory/NSF

Stargazing for Life

A year isn't long enough to get to know the night sky in detail, but that's not what stargazing needs to be about. Getting to know the constellations, planets, some double stars, several beautiful star clusters and the occasional distant nebula has, I hope, been a real adventure. Getting a fix on the celestial mechanics, and the seasonal rhythms of the sky are some of the most enlightening things a person can know.

You've hopefully also learned that a stargazer's best friends don't have to be complicated telescopes, computers and hefty textbooks. Much more important are a trusty pair of binoculars, warm feet, clear dark skies, and buckets of both enthusiasm and patience.

Now go spend some time with eternity.

References

Consolmagno, Guy & Davis, Dan M. Turn Left at Orion: 4th Edition. Cambridge University Press, Cambridge. 2011.

Holberg, J.B. Sirius: Brightest Diamond in the Night Sky. Springer Science & Business Media, Berlin Heidelberg New York. 2007.

Kaler, James B. First Magnitude: A Book of the Bright Sky. World Scientific Publishing, Singapore. 2013.

Kaler, Jim. Stars. [ONLINE] Available at: http://stars.astro.illinois.edu/sow/sowlist.html. [Accessed 01 June 15]. 2009.

Kaler, Jim. Stars. [ONLINE] Available at: http://stars.astro.illinois.edu/sow/sowlist.html. [Accessed 01 June 15]. 2015.

Mollise, Rod. The Urban Astronomer's Guide: A Walking Tour of the Cosmos for City Sky Watchers. Springer-Verlag, London. 2006.

Rao, Joe. Great Star of the South. [ONLINE] Available at: http://www.space.com. [Accessed 02 June 15]. 2005.

Schaaf, Fred. The Brightest Stars: Discovering the Universe through the Sky's Most Brilliant Stars. John Wiley & Sons, New Jersey. 2008.

SolStation Pollux. [ONLINE] Available at: http://www.solstation.com. [Accessed 05 June 15]. 2011.

Tonkin, Stephen. Binocular Astronomy, Second Edition. Springer New York Heidelberg Dordrecht London. 2014.

Tonkin, Stephen. The Christmas Tree Cluster, Binocular Tour. BBC Sky At Night magazine January 2015, Immediate Media, Bristol. 2015.

PART IV

DARK SKY DESTINATIONS

CHAPTER 13

UPSIDE-DOWN STARGAZING

The Southern Sky

Head south and the sky is upside-down. Confusing, baffling and yet surprising and spectacular, stargazing in the southern hemisphere is like meeting a long lost sibling, or reading a newly discovered book by your favorite author.

If you live in the northern hemisphere, any experience with the a southern sky is likely to be fleeting, most likely on vacation in Australia, South Africa or South America.

I spent an entire year in Australia when I was in my mid-twenties. I wasn't a stargazer back then, and in my time in the vast country I looked at the night sky properly only once while camping out in a bivvy bag near Uluru, or Ayer's Rock, in the country's Red Center. It was a real 'blanket of stars' moment, and on that Moon-less night I remember feeling completely disorientated. I recognized nothing. My regret is that I didn't ask why that was.

Celestial Set-Pieces

It's only over a decade later that I know what I was missing. The southern hemisphere is a stargazer's dream destination. It does have dark skies—some of the darkest on the planet—and many high altitude areas, too, though that doesn't fully explain why almost all of the world's biggest and best telescopes are built south of the equator.

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_13

The reason is that from places like South Africa, Argentina, Chile, Australia, Fiji and New Zealand it's possible to see some of the night sky's most intriguing sights.

Why is the southern hemisphere the only place to be for astronomers? Simple: while the North Pole faces outwards to the Universe beyond, the South Pole points to the galactic center of the Milky Way. That has obvious consequences for stargazing; there are billions of stars, and more bright stars, more constellations containing more objects in the southern skies. What's more, they're circumpolar—they rarely set. It's a celestial set-piece that stargazers find hard to resist.

New World Wonders

Traveling south can be disorientating. Even if you know your constellations very well, it can be difficult to find them. When you do finally spot them, they're often upside-down and positioned next to constellations and bright stars you've never seen or even heard of before. It soon becomes clear that everything you've learned about the night sky is only half the story.

While the southern stars are baffling, after a few stargazing sessions the sky starts to shrink since a lot of the constellations you know well are in the sky somewhere—you've just got to find them.

When you stargaze may change. The equinoxes and solstices are reversed, so nights begin to draw in from March and the longest day of the year is in December. Whenever you visit the southern hemisphere, the rule is simple; constellations that northerners think of as circumpolar—such as the Big Dipper, Cassiopeia, Draco and Cepheus—are seasonal down south. Think about the 'spring up, fall down' memory aid for the Big Dipper (Chap. 1). Because of the curvature of the Earth, when the Big Dipper is down in the fall—the southern hemisphere spring—it's invisible below the equator. Similarly, the North Star, Polaris (Chap. 1), is not visible from anywhere south of the equator at any time. When the Big Dipper is up in the north in spring, stargazers enjoying fall in the southern hemisphere simultaneously see it in the northern sky.

Orion, a winter constellation high in the northern hemisphere's southern sky in January, is making an upside down appearance south of the equator as a fleeting summer constellation. His sword points upwards while Betelgeuse is low on the northern horizon. Ditto Taurus and Canis Major, while Sirius sits overhead at the zenith.

Also consider the Summer Triangle (Chap. 6). In the northern hemisphere, Deneb and Vega shine brightly high in the sky overhead with Altair below closer to the horizon. South of the equator, Altair is on top, and you can watch Deneb and Vega sink as the night continues. It's genuinely disorientating and, of course, down there this three-pronged asterism is called—you guessed it—the Winter Triangle.

The Crux of the Matter

So what have they got that we haven't? Well, quite a lot … so much so, in fact, that many stargazers travel south specifically to see them. The Southern Cross, or Crux, is perhaps the most famous, and though it's not anywhere near to the south pole, it's just as useful as Polaris for navigation, if you know how to star-hop. You soon will.

Since few visitors will have a telescope to hand during a vacation in the southern hemisphere, most of the sights included in the chapter are for naked eye and binoculars, though there are a few objects here that look even more stunning in a telescope. When visiting the southern hemisphere, try to find a observatory that holds hold public stargazing and observing sessions using telescopes, or a resort or guesthouse that has a telescope available for guests. Such are the wonders of the southern night sky that places like these are more common than you might think. Something else I always take—everywhere I go—is a printed star chart downloaded from SkyMaps,[1] which makes available versions for the northern, equatorial and southern skies. It even includes an astronomical calendar of eclipses, conjunctions, lunar positions and other not-to-be-missed moments that month.

[1] http://skymaps.com

The Southern Hemisphere Hit-List

Naked Eye and Binocular Target: The Upside-Down Moon

What phase is the Moon in? From the southern hemisphere, it can be difficult for northerners to tell when they first arrive. Everything we northerners see in the southern part of the celestial sphere—including along the ecliptic (Chap. 3)—will appear upside-down when we cross into the southern hemisphere. That includes the Sun and Moon (Fig. 13.1). Here's the proof that we don't live on a flat planet. Since it orbits near the equator, the Moon is therefore not only in the northern sky, but it's upside-down.

Take a closer look at the Moon through binoculars and the sight of the Sea of Tranquility, Sea of Serenity and Sea of Fertility all orientated the 'wrong' way is strange indeed.

Naked Eye and Binocular Target: The Sagittarius Arm of the Milky Way and the Great Rift (June–September)

Though it's impossible for us to get a bird's eye view of the galaxy we live in, but we can get our very best views of it only from the southern hemisphere. Down here we can see the Milky Way's innermost, brightest Sagittarius Arm—it glows because it covers the galaxy's bright core—and we can see the Great Rift (Chap. 7), a spectacular dark nebula of dust clouds. These clouds, which look like dark areas between the rich star-fields of the Milky Way, are only about 300 light years away (the center of the Milky Way is 25,000 light-years distant), and they block our view of the stars behind.

It's very easy to find. We've already looked at the Milky Way descending through the Summer Triangle from Deneb through Altair. It's here that the Great Rift begins. Find Deneb or Altair (the latter will be highest in the sky) and trace the Milky Way across the zenith and down to Alpha Centauri and the Southern Cross above the southern horizon (Fig. 13.2). It's a demonstration of just what we miss out on in the northern hemisphere.

Fig. 13.1 To travelers from the northern hemisphere, the Moon looks upside-down from southern latitudes, such as here in the Atacama Desert in Chile. Credit: ESO/Sergio Otarola

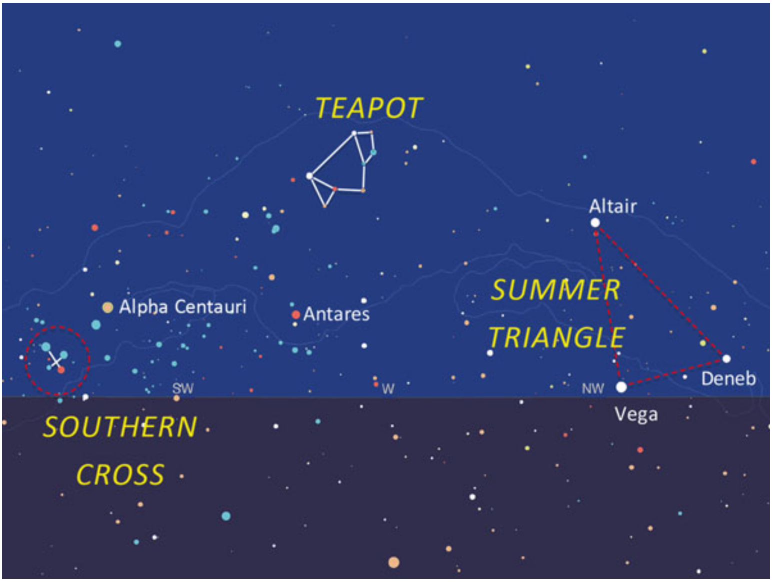

Fig. 13.2 The southern sky seems familiar yet strange to visitors from the northern hemisphere; find the upside-down Summer Triangle and it will lead you to the Teapot, with Alpha Centauri and the Southern Cross in the south-west (July–September)

The best time to see the Great Rift is between July and September, when the Milky Way stretches overhead.

Naked Eye Target: Alpha Centauri: The Next Visible Star System Along (March–September)

Everybody knows the next town along from where they live, but how about the nearest star to our Sun? The clue is in the name: Proxima Centauri, a red dwarf star just 4.24 light-years from us. It's in the (rather complicated) constellation of Centaurus, which is only visible from the southern hemisphere. Proxima Centauri is also too faint to be seen with the naked eye, which is probably why it's little-known. So how about the nearest visible star (other than the Sun)? That's Proxima Centauri's much brighter companion, Alpha Centauri, which also happens to appear to be the third brightest star in the

sky (Fig. 13.2). Also known as Rigil Kent, it's 4.3 light-years from Earth. It's actually a double star itself, made from two Sun-like stars, though together with tiny Proxima Centauri, Alpha Centauri is a triple star system.

If you live below about 25 degrees north, you might see Alpha Centauri peek above the southern horizon; it was worshipped by the Egyptians, who erected temples at Corinth and Delphi with special alignment to the rising of this star (MuseumVictoria 2013). To watch Alpha Centauri and ponder whether humans might one day visit this star system is a special treat when traveling to the southern hemisphere. However, it would take tens of thousands of years to reach Alpha Centauri or Proxima Centauri on current rocket technology. It's probably best we wait for a technological breakthrough before contemplating a trip, but navigating home would be easy; in Alpha Centauri's night sky our Sun would appear as a bright star close to Cassiopeia.

Naked Eye Target: The Southern Pointers (March–September)

If you want to point out the nearest star to our solar system to companions, do be careful; Alpha Centauri has a close neighbor that's bright though much, much further away. Beta Centauri, or Hadar, the less bright of the two, is 390 light years distant and 10,000 times brighter than our Sun. It's actually two stars orbiting each other. Alpha Centauri and Beta Centauri—both in the constellation of Centaurus—are together called the Southern Pointers because they point straight to Crux, the Southern Cross (Figs. 13.3 and 13.4). If you don't use the Southern Pointers and instead rely on your keen stargazing skills, you may fall into the common trap of identifying what's known as the False Cross, a bigger asterism within the constellation of Carina to the east (Fig. 13.3).

Star-Hop to the Southern Cross (March–September)

Locate Alpha Centauri and Beta Centauri. Starting at Alpha Centauri, go three times the distance between those two stars and you'll arrive at Gacrux at the top of the Southern Cross. Note that the Southern Cross is a circumpolar constellation, so this star-hop can take you in any direction depending on the time of night and the time of year.

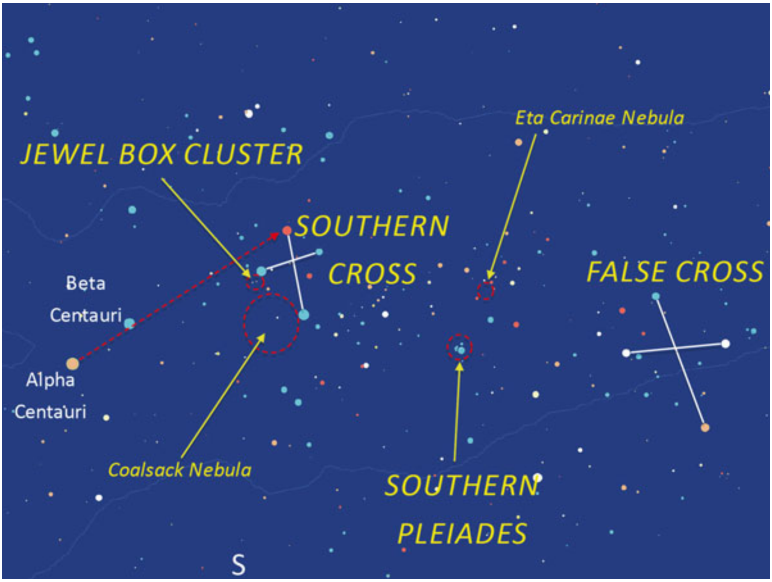

Fig. 13.3 In this busy area of the southern hemisphere sky are the Southern Pointers, the Southern Cross, the False Cross, the Jewel Box cluster, the Coalsack Nebula and the Eta Carinae Nebula

Fig. 13.4 The Southern Cross and Alpha Centauri straddling the Milky Way is an arresting southern hemisphere sight. Credit: ESA & A. Fujii

Naked Eye Asterism: The Southern Cross (March–September)

The southern hemisphere doesn't have a pole star, but when it comes to both navigating and stargazing, there's only one constellation in town—the Southern Cross (Fig. 13.4). It is the brightest and the most famous of all southern sky shapes, and can be found on the flag of Brazil, and even more prominently on the flags of Australia and New Zealand.

Crux is most easily seen between March and June, when it's highest in the sky. It can even be just visible from lower latitudes of the northern hemisphere. The Pointer Stars will be in the east from March until June, though from July to September the Pointer Stars will be above Crux, which will be lower in the sky.

Take a line through those Pointer Stars and you'll come to Gacrux, an orange star at the top of the cross that's closest to us at about 88 light years distant. A right-angle takes you to the bottom of the cross, to Acrux, the brightest in the constellation and the 12th brightest star in the night sky. It's 320 light years from us, while the remaining left and right stars of the cross, Becrux (sometimes called Mimosa) and back towards the Pointers, and fainter Delta Crucis, are 350 and 364 light years away. Between Delta Crucis and Acrux is a fifth star, orangey Epsilon Crucis, which is 230 light years distant. It's depicted on the Australian flag despite being rather dim.

If you're looking for something to rival the Northern Cross (Chap. 7), Winter Circle (Chap. 2) or the Summer Triangle (Chap. 6) from the northern hemisphere, you may initially be disappointed by the tiny size of Crux, but around it are some of the night sky's very finest sights.

Sweep your binoculars across this region of the Milky Way and you're confronted with numerous stunning star clusters, so much so that it's left many a northern stargazer deeply jealous of their southern counterparts.

Binoculars and Telescope Target: The Jewel Box Cluster, NGC 4755 (March–September)

Fans of the Perseus Double Cluster (Chap. 11) over in the Perseus Arm of the Milky Way will find a sister sight in the southern hemisphere of a similar age and distance—and you don't have to move far from Crux. A mix of over 100 sparkling red and blue stars, the Jewel Box cluster is well named, and great to look at through binoculars or a small telescope. Around 6400 light-years away and also known as the Kappis Crucis Cluster and NGC 4755, it's easily found. Visualize a line from Gacrux at the top of the cross through Becrux on the eastern side of the cross, and keep going for a just quarter of the distance of that line (Fig. 13.3). You'll hopefully see what may look like a single star with your naked eye. Train your binoculars on it and you should see about four stars. In a telescope it's revealed as a bright open cluster of sparkling giant blue stars with an orange supergiant in the center (Fig. 13.5). The contrast is stunning. The Jewel Box Cluster is reckoned to be a mere seven million years old.

Fig. 13.5 The Jewel Box cluster as seen by the ESO Very Large Telescope (VLT) at ESO's Paranal Observatory in Chile. Credit: ESO/Y. Beletsky

Binocular Target: The Coalsack Nebula (March–September)

Don't rush this one. Range slightly below the Jewel Box Cluster and you'll come to a dark band over the Milky Way (Fig. 13.3). An interstellar dust cloud that prevents the light from stars within the Milky Way from reaching us, the Coalsack is just 600 light years away. Range your binoculars over it and you won't see much; the stars that are visible are actually in front of it. This dark nebula constitutes the remains of exploded stars, and will go on to become the birthplace of new stars. If you're in a dark sky site and can see an otherwise bright Milky Way, the Coalsack is pretty obvious if you look for long enough.

Star-Hop: Find the South Pole in Winter (March–September)

We've got it easy in the northern hemisphere; navigating south using the stars isn't nearly as easy. The celestial south pole lies in the constellation of Octans, but that is such a faint constellation that few use it to find the south celestial pole. Remember that we're not looking for a point on the horizon, but a point in the sky that we can then drop down to the horizon from, as we can do very easily in the northern hemisphere from Polaris (Chap. 1).

First visualize a line between Gacrux at the top tip of the Southern Cross to Acrux at the bottom. Now draw a line perpendicular to the Southern Pointers—so cutting through their counterpoint—that extends to meet the line from Gacrux to Acrux (Fig. 13.6), and you've found the south celestial pole.

Naked Eye Target: Canopus, the Great Star of the South (October–May)

You can't miss Canopus, the second brightest star in the sky after Sirius (Chap. 1). Further away from us at 313 light years (Sirius is a mere 8.7 light years distant), Canopus is much brighter—a stunning 12,000 times brighter than our Sun, and 65 times larger. Around 40 degrees below Sirius,

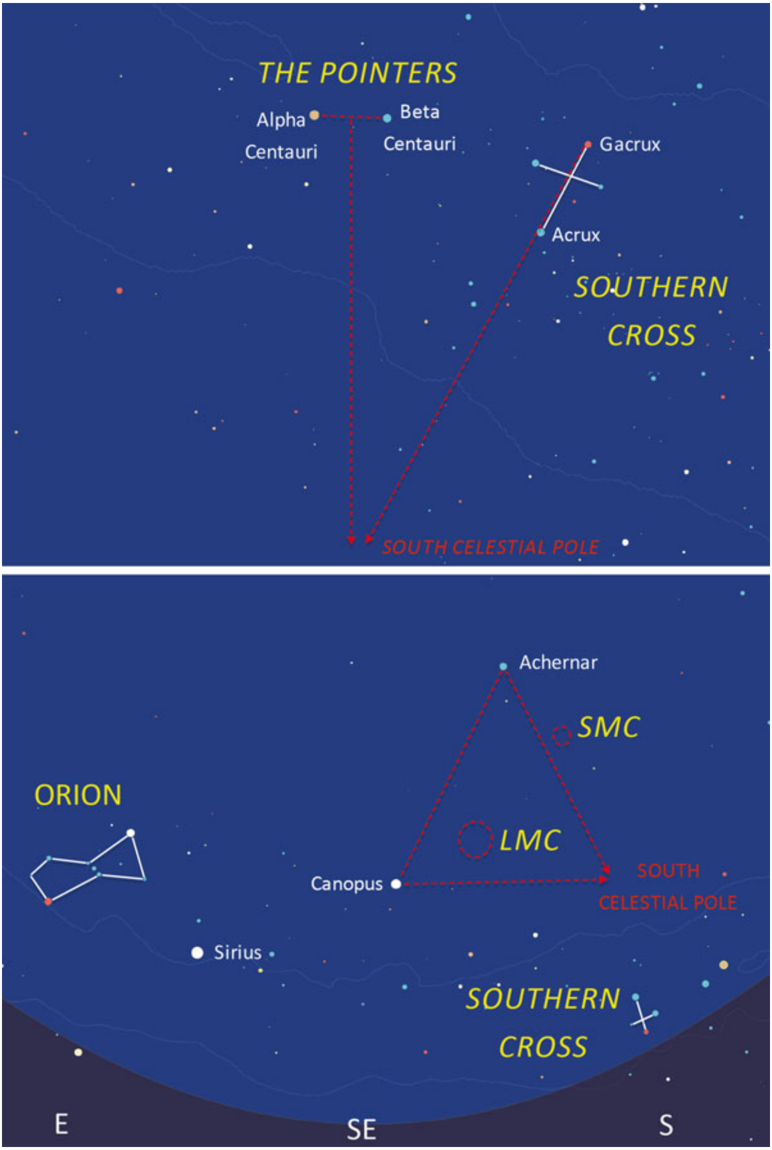

Fig. 13.6 **How to find the south celestial pole in winter (*top*) and summer (*bottom*)**

Canopus can easily be found from October through May high in the southern sky (Fig. 13.6). For most of that time it's joined by Sirius.

Star-Hop: Find the South Pole in Summer (October–February)

The Southern Cross helps you find the south celestial pole, right? Absolutely, but there's a problem. From October through March—summer in the southern hemisphere—you won't see the Southern Cross during the night, so we need another way of locating south. During this time of year, navigators use Canopus and Achernar, in the constellation of Eridanus, the ninth brightest star in the night sky. It's fairly easy to spot; it lies on the other side of Canopus to Sirius, the latter of which you should be able to identify easily if Orion's Belt is visible by star-hopping (Chap. 1), only upside-down. Visualize a straight line between Canopus and Achernar and imagine an equilateral triangle below that covers a couple of fuzzy patches of sky (Fig. 13.6); at the point of the third, absent star is the south celestial pole. Draw a line to the horizon and you'll have found the general direction of south.

Naked Eye Targets: Small and Large Magellanic Clouds (October–February)

If you've found Canopus and Achernar, then you've probably already noticed two fuzzy patches; these are two of the objects in the night sky that stargazers and astronomers travel south of the equator specifically to observe. While the northern hemisphere has a great view of the Andromeda galaxy, folks in the southern hemisphere have the Small Magellanic Cloud (SMC) and the Large Magellanic Cloud (LMC), too (Fig. 13.7). These two small dwarf galaxies are satellites of the Milky Way, and they look huge. So big, in fact, that I've heard of some stargazers complaining that the southern hemisphere is too cloudy until they realize just what they're looking at, and hastily pick-up their binoculars to gaze at the dense star-fields within.

Around 160,000 light years distant, the LMC is higher and bigger in the sky, while the SMC is smaller, just below the LMC, and over 200,000 light years away. They were named after Portuguese explorer Ferdinand Magellan,

Fig. 13.7 The Small and Large Magellanic Clouds soar high above Cerro Paranal and the VLT in Chile. Credit: ESO/B. Tafreshi (twanight.org)

who spotted them in 1519 while circumnavigating the globe for the first time. Although they're both circumpolar, they're best seen when highest in the sky on a dark, Moon-less night between September and April (Fig. 13.9).

The LMC contains the Tarantula Nebula, which is best thought of as a super-massive version of the Orion Nebula (Chap. 4). One hundred times larger, this is the biggest star-forming region in our part of the Universe, and so luminous that if it was as close to us as the Orion Nebula is (about 1300 light years), it would cast a shadow on Earth at night (NASA 2012).

Binoculars and Telescope Target: 47 Tucanae, NGC 104 (October–February)

Just west of the Small Magellanic Cloud is 47 Tucanae, the second brightest globular cluster (Chap. 5) in the Milky Way (the brightest is coming up soon). In binoculars it appears as a single fuzzy star with a halo around it,

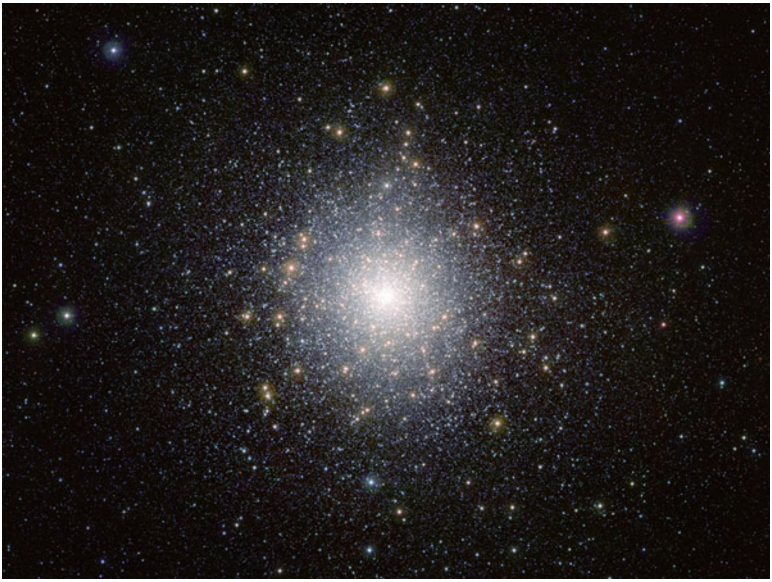

Fig. 13.8 Globular cluster 47 Tucanae from the Paranal Observatory in Chile. Credit: ESO/M.-R. Cioni/VISTA Magellanic Cloud survey

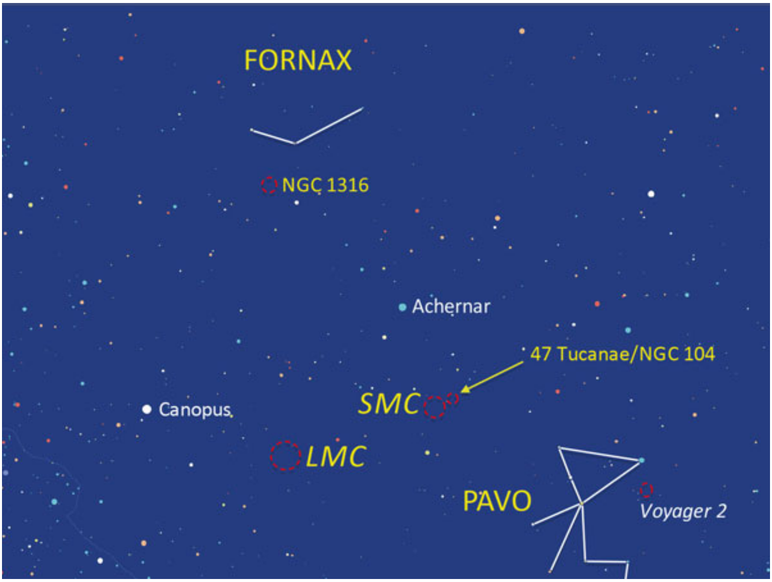

Fig. 13.9 The Small and Large Magellanic Clouds, 47 Tucanae, Fornax, Canopus and the location of the space probe Voyager 2 in the constellation of Pavo (September–April)

but it's noticeably brighter in the center—wow! It's impressive, but this is one to get some magnification on; in a telescope it's like 'cracking open a geode and finding it filled with gold dust' (O'Meara 2013) (Fig. 13.8). It's on the opposite side of the SMC to the LMC (Fig. 13.9). 47 Tucanae is 13,400 light years distant and about 10.5 billion years old.

Naked Eye Constellation: Fornax (November–January)

Draw a line from the SMC through Achernar and you'll come to a faint, flat V-shape constellation called Fornax (Fig. 13.9), which is best seen from November to January. There's little to see here; this part of the night sky is away from the Milky Way spiral arms, and empty. At least, it looks that way. Close by is NGC 1316, a galaxy about 70 million light years distant in the Fornax Cluster—the next cluster along from our own Virgo Cluster (Chap. 5), where resides the Fornax A black hole, one of the strongest sources of radio in the Universe. However, there are thousands of galaxies here, which is why the Hubble Space Telescope has been pointed at it many times, most recently producing the exquisite Hubble eXtreme Deep Field, or XDF, in 2013 (Fig. 13.10).

Naked Eye, Binoculars and Telescope Target: Omega Centauri/NGC 5139 (March–September)

A globular cluster with the naked eye? This 13 billion year old, 1 million star-strong globular will appear under dark skies as a fuzzy blob to the naked eye, a bright bulge in binoculars, and plain stunning in any size of telescope.

Go back to the Southern Pointers, and locate Beta Centauri, the star nearest to the Southern Cross. Above Beta Centauri is Epsilon Centauri, or Birdun. Check you've gone the right way by making an equilateral triangle with Beta Centauri, Epsilon Centauri and Becrux on the left-hand side of the Southern Cross (Fig. 13.11). We're now deep into the constellation of Centaurus. Visualize a line between Beta Centauri and Epsilon Centauri, and go the same distance again, and you have found Omega Centauri. It's thought that it's the nucleus of a dwarf galaxy that collided with our own.

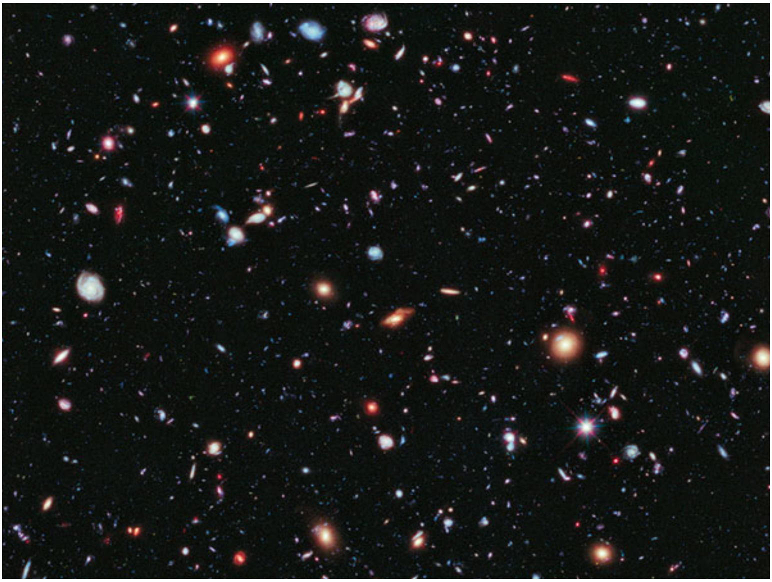

Fig. 13.10 The Hubble eXtreme Deep Field photograph of 2012 contains a dumb-founding 5500 galaxies, and was taken within the constellation of Fornax. Credit: NASA; ESA; G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team

Binocular Target: Centaurus A Galaxy, NGC 5128 (March–September)

Range your binoculars up from Omega Centauri and you'll come to Centaurus A, or NGC 5128, the fifth brightest galaxy in the sky. Part of the Virgo Supercluster (Chap. 5), Centaurus A is 11 million light years away and is actually two galaxies crashing into each other, though you'll need a small telescope to discern the vast dust lane across the middle. In a very dark sky, you may be able to glimpse this unusual galaxy with the naked eye (Fig. 13.11).

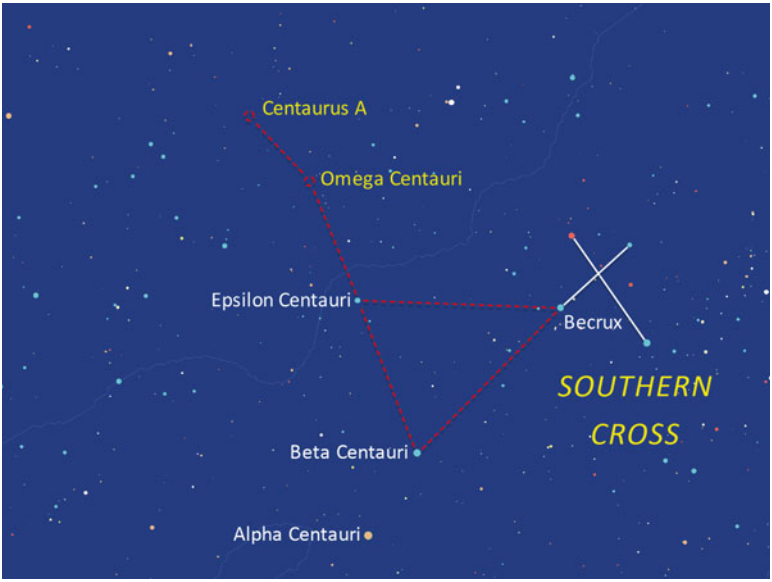

Fig. 13.11 Globular cluster Omega Centauri and Centaurus A galaxy can be seen near the Southern Cross

Binocular Target: Eta Carinae and the Southern Pleiades (February–July)

Northerners tend to speculate on whether Betelgeuse will go supernova anytime soon (Chap. 2), but actually the top candidate for a gigantic explosion is the most massive star of all, Eta Carinae. It's also one of the top sights south of the equator. A bright orange star just a few million years old, it's 100 times bigger than the Sun and five million times more luminous. However, you'll probably need binoculars to spot it (Fig. 13.3). Finger's crossed it goes supernova while you're trying to find it (if that happens, instantly retire from stargazing—you'll never beat that!).

Circumpolar below latitude 30 degrees, it's found at the center of (and is partially responsible for) the Great Nebula in Carina, NGC 3372, a diffuse nebula around 9000 light years distant similar to the Orion Nebula and the Tarantula Nebula.

If you range your binoculars below the plane of the Milky Way you'll likely spot a beautiful open cluster around 479 light years away called the Southern Pleiades (Fig. 13.3). Look for a bright star in the center and four others around it arranged as cardinal points; a classic binocular sight.

Telescope Target: Saturn (April–August)

Think this is a universal sight? Since it traverses the same ecliptic as the Sun and the rest of the planets, technically the Ringed Planet can be seen from anywhere on Earth. However, it's currently moving through the zodiacal constellations that are low on the southern horizon for us in the northern hemisphere. Consequently, Saturn is often lost in the haze and can be difficult for backyard stargazers to spend much time with. That's not going to get any better anytime soon, as Saturn—on its 29 year orbit around the Sun—will move through the constellations of Scorpius, Ophiuchus, Sagittarius and Capricorn until the mid 2020s. All of those constellations are easiest to see from April to August in the southern hemisphere.

The year 2017 is a good time to look at Saturn because its rings will be open and mightily impressive (a 4-inch telescope is enough for a view of the rings), though if you don't make it down south until 2030, there's less need to travel because Saturn will be high in the sky in the constellation of Taurus near the Pleiades (Chap. 2), easily visible in the northern hemisphere for many years after.

Binocular Targets: Northern Hemisphere Stars

Just because you're in the southern hemisphere that doesn't mean you can't get a different, and sometimes a much better, view of the same stars you've spent all year learning about. If you've traveled into the Australian Outback, headed up the Inca Trail in the High Andes in Peru, or are on safari deep in the African bush, you've found the perfect place to get your best-ever view of some of the jewels of the northern hemisphere. What you'll be able to see will depend on what time of year you are there, of course, but

the northern hemisphere's winter constellations (Chaps. 1, 2 and 3) will be visible from the southern hemisphere at exactly the same time, and vice versa.

So if you're down south in a dark sky site from January to March, have a quick look at the Orion Nebula in January and the Beehive Cluster in March. In August and September have a look for Sagittarius and the Andromeda galaxy.

Mind's Eye Target: Voyager 2 in Pavo (June–September)

The sister probe of Voyager 1 (Chap. 6) on NASA's Grand Tour of the solar system, Voyager 2 took advantage of a chance alignment of the outer planets to travel to, and photograph them. Launched in 1977 a few weeks before Voyager 1, it traveled more slowly, but also reached both Jupiter and Saturn. However, its claim to fame is that it is the only spacecraft to visit Uranus and Neptune, which it did in 1986 and 1989. Every photo you've even seen of Uranus and Neptune was taken from Voyager 2 on a fly-by before it exited the solar system. By 2015 it was around 107 AU, and 30 light-hours, from the Sun (JPL 2015). It's traveling in the direction of the circumpolar constellation of Pavo (Fig. 13.9), whose bright star Alpha Pavonis can be found if you travel in a straight line from Canopus via the LMC and the SMC.

References

Jet Propulsion Laboratory (JPL). Where are the Voyagers? [ONLINE] Available at:http://voyager.jpl.nasa.gov/where. [Accessed 02 June 15]. 2015.

Museum Victoria. Sky Tour for Binoculars: Crux & Centaurus. [ONLINE] Available at:http://museumvictoria.com.au. [Accessed 02 June 15]. 2013.

NASA. Hubble's Close Encounter with the Tarantula. [ONLINE] Available at: http://www.nasa.gov. [Accessed 02 June 15]. 2012.

O'Meara, Stephen James. Deep-Sky Companions: Southern Gems. Cambridge University Press, New York. 2013.

CHAPTER 14

ECLIPSES AND AURORAS

Stargazing Without the Stars

There are rare and spectacular celestial phenomena that have little to do with constellations and stars. Perhaps the most famous is a solar eclipse, when the Moon's shadow races across a narrow band of the Earth's surface. Those below experience a blackout and see a 'hole in the sky' (Fig. 14.1). A lunar eclipse is viewable from far larger areas. It's much more subtle, but a copper colored Moon is a beautiful sight. Lastly comes the aurora, spectacular seasonal displays of magnetic activity. Pulsing greens curtains dance around the poles in what's known in the northern hemisphere as the Northern Lights. See all of these phenomena and you've achieved a celestial hat-trick.

What Is an Eclipse?

There are two different types of eclipse, solar and lunar. A solar eclipse occurs when the Moon passes in front of the Sun, and a lunar eclipse when the Moon passes into Earth's shadow.

Why Eclipses Are So Rare

If the Moon followed the ecliptic perfectly, we would expect to see both a solar and a lunar eclipse every month. The reason they are so rare is because the Moon's orbit is both elliptical and titled, so it only passes through the ecliptic occasionally. It's only when a New Moon crosses the ecliptic that a solar eclipse can occur. Likewise, a lunar eclipse only happens

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_14

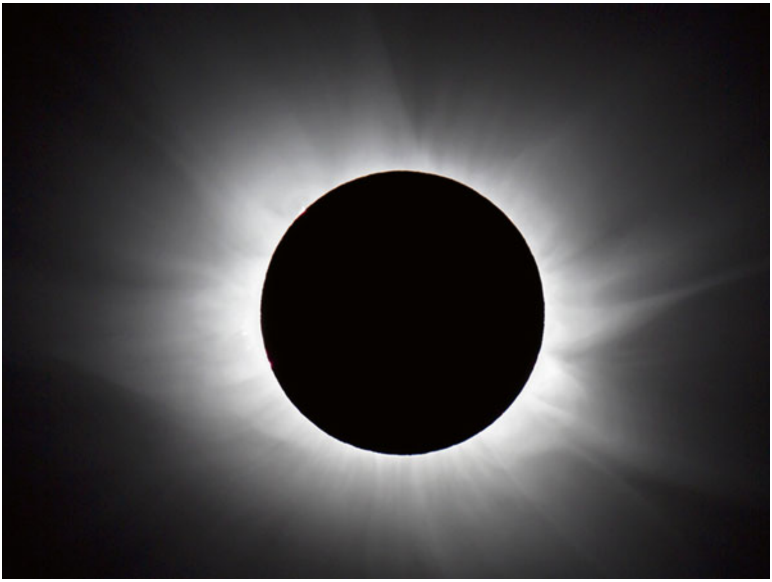

Fig. 14.1 A totally eclipsed Sun from the Faroe Islands, March 20, 2015. Credit: Nick Glover

when a Full Moon crosses the ecliptic. Both events are rare, but predictable down to the second.

Since the Moon's shadow on Earth is small, few people get to see an eclipsed Sun. Since the shadow Earth projects into space is huge, anyone on the night-side of the planet can at least see part of a lunar eclipse.

Eclipses: Lunar Versus Solar

Aside from being on the opposite sides of the sky, lunar and solar eclipses are very different. Lunar eclipses are more flexible. A total lunar eclipse occurs when the Moon drifts into the shadow of the Earth, but that shadow is always there. Even if the Moon was a little bigger, closer, smaller or further away, lunar eclipses would still take place.

That's not the case with a total solar eclipse, which is a fluke of celestial alignment. The mechanics are such that to us on Earth the Moon and Sun often appear to be exactly the same size. The Sun is 400 times larger in diameter than the Moon, but 400 times further away. The match-up is exact and, for a brief time, the Moon completely covers the Sun. At this point there is a blackout and it's possible to see the Sun's mighty corona. This is called totality.

Solar Eclipses

A total eclipse of the Sun is one of the most visually and even emotionally spectacular natural events anyone could hope to see. Those who have yet to see the Moon block out the Sun for a few precious minutes may doubt that assertion, but the event gives such a powerful sense of the tremendous depth of the solar system that every stargazer should try to catch a total solar eclipse.

Types of Solar Eclipses

There are various types of solar eclipses, and it's best to know one from the other before you make plans to travel across the globe to witness one.

Partial Solar Eclipse

During a partial solar eclipse the Moon appears to take a chunk out of the Sun (Fig. 14.2). A 'smiley face' crescent Sun is an event in its own right, but at no point does the Moon block all of the Sun's light, so it never gets completely dark. However, it can be a deeply affecting event if the Moon covers anything more than about 85 % of the Sun, especially on a clear day, when the level of daylight noticeably dips. How much of the Sun the Moon blocks will depend on where you are on the Earth's surface, but at least some of a partial eclipse can be viewed from a track many hundreds of miles wide.

Fig. 14.2 A partially eclipsed Sun is a beautiful sight, but dangerous to look at without solar safety glasses. Credit: NASA/Bill Ingalls

A partial eclipse is potentially dangerous to observe. It's not possible to look at the Sun with a bite taken out of it unless you're wearing special solar safety eclipse glasses. Some light cloud can offer a brief glasses-free glimpse of the event, but never view a clear partial solar eclipse with the naked eye.

Total Solar Eclipse

There are two attractions of a total solar eclipse. The first is that for a few precious minutes you can look at the Sun's corona without safety glasses. It's a stunning sight (Fig. 14.3). The second reason is to stand under the Moon's shadow as it causes a complete blackout all around you. While seeing the corona is dependent on clear skies, the blackout is intensified by cloud. However, a clear sky is preferable, not least because it also lets you see a long partial eclipse either side of totality.

Fig. 14.3 A total solar eclipse above the Faroe Islands, March 20, 2015. Credit: Visit Faroe Islands/Bardur Eklund

You'll need to be on a very narrow track on the Earth's surface (known as the line of totality) to witness a total solar eclipse, but it's worth crossing continents for.

Annular Solar Eclipse

The third type of solar eclipse is, like a partial eclipse, dangerous to look at with the naked eye. It happens when the Moon is at apogee—its furthest point from the Earth in its elliptical orbit—so the Sun appears slightly bigger in the sky. The Moon covers most, but not all, of the Sun, creating what's known as a Ring of Fire eclipse. Total darkness doesn't occur during an annular eclipse, and solar safety eclipse glasses must be worn.

The Key Moments of a Total Solar Eclipse

A total solar eclipse is the type worth traveling to see, and it begins when the Moon 'kisses' the Sun on one side, and ends when it 'kisses' it goodbye on the other. In between those two moments, which are about two hours apart, are some of the rarest and most beautiful celestial phenomena of all.

First Contact

The spectacle begins with a long partial eclipse phase lasting around an hour. The edge of the Moon appears to touch the Sun, and take a bite that gets bigger while the light fades; you'll need solar filter glasses to see this safely. A slotted spoon or a colander is also handy. With some blank card in one hand, hold up the spoon or colander above it at arm's length to get tiny crescent Suns projected onto the card (Fig. 14.5).

Baily's Beads

About 10 seconds before and after totality, beads of the only remaining visible sunlight pour through the valleys of the Moon. Just before the Sun is completely blocked, the last rays create a magical Diamond Ring around the Moon that signals the start of totality. Only now can you take off your solar safety glasses (Fig. 14.4).

Crescent Suns and Shadow Bands

Just before Second Contact (see below) shadows are crisper and sharper all around you. If there are trees nearby look on the floor beneath them for crescent Suns filtered by the leaves. If you're on a beach, a desert or on snow look for dark shadow bands that ripple across the ground just before and after totality, a phenomena that scientists still can't explain. It appears to have something to do with how the crescent sunlight is refracted through Earth's atmosphere.

Fig. 14.4 Even during a total solar eclipse, solar safety glasses are essential for all but totality © Jamie Carter

Second Contact

As the two celestial bodies line-up, an eery light falls on those standing under the growing Moon shadow. Light levels start to dwindle until the strangest silvery twilight overtakes everything but the horizon, which remains brightly lit.

Totality

After Baily's Beads have finished dancing on the Moon's edge all sunlight ceases and the corona suddenly flashes into view. There's a hole in the sky, a truly spectacular sight. Many think the Sun is yellow, but those who've stood under the shadow of the Moon during a total solar eclipse know different. The corona appears as bright, white ribbons billowing in a breeze. This is the time to pick up your binoculars and look around the edges for bright red prominences, huge solar flares and explosions on the surface of the Sun (Fig. 14.6).

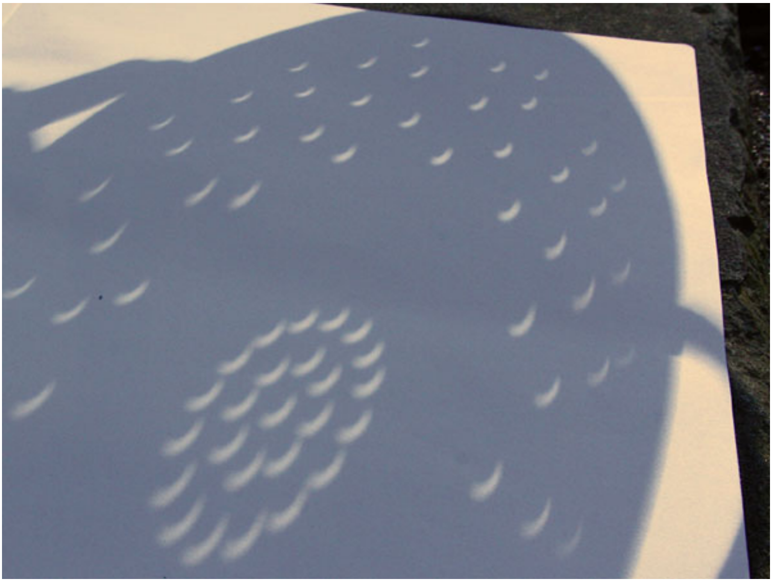

Fig. 14.5 During a partial eclipse, crescent Suns can be projected onto card through a colander © Gill Carter

During totality don't forget to look for planets, if there are any nearby. Plan ahead by looking at a stargazing app. Though the Sun's corona is an intoxicating and preciously short sight, it's also worth having a brief look around you at the different colors, the eeriness and the effect of the eclipse on the sky behind you (as well as on the people around you – most fall utterly silent in awe).

With the Sun blocked for a few minutes, there can also be a drop in temperature. There is a slight lag, but if you're somewhere particularly hot or humid, the temperature change can be dramatic (Fig. 14.6).

Third Contact

As the Moon moves away from the Sun, the entire spectacle goes into reverse. Bailey's Beads appear on the opposite side until there's a powerful flash of yellow or even pink light from the emerging Sun, and the famed Diamond Ring; Third Contact is achieved. Totality is over, and the solar safety glasses must go back on.

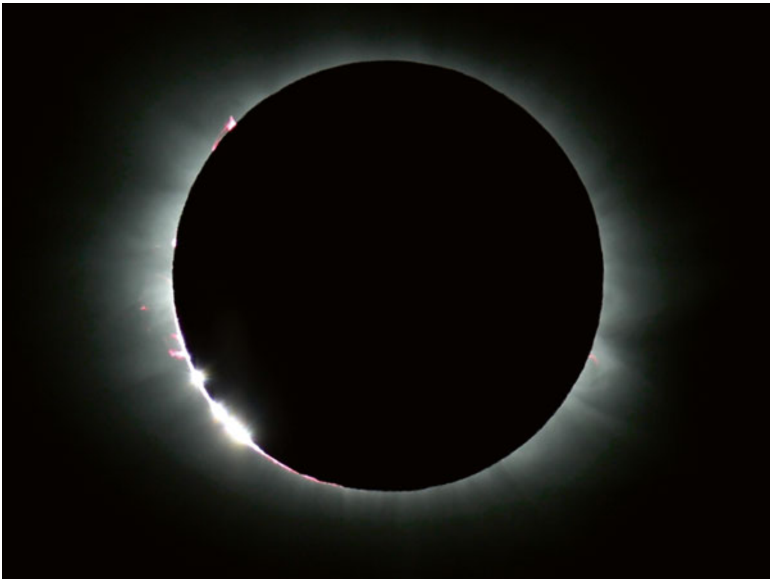

Fig. 14.6 Solar flares and prominences can be seen during totality. Credit: Nick Glover

Fourth Contact

From the end of totality until Fourth Contact, when the two bodies drift apart, there's another long partial eclipse. At this point totality junkies begin to drift off, having seen what they came for. That's a shame because a partial eclipse is a spectacular and rare event in its own right, and demands to be observed.

Totality or Bust!

A total solar eclipse is far more impressive a partial eclipse. The difference between watching a 99 % eclipsed Sun and a totally eclipsed Sun is huge. It all happens within the last 15 seconds when the sun goes from 99.9 % covered to 100 % covered—and it's that 0.1 % that makes all the difference. It's that exact match-up between Moon and Sun that enables us to stare at the Sun's corona.

Eclipse-Chasing

To eclipse means to obscure, and some would use that word to describe the hobby of chasing the shadow of the Moon around the world. Hordes of eclipse-chasers hooked on this once-in-a-lifetime spectacle are determined to make it anything but. Many eclipse-chasers meet-up once a year or so in random parts of the globe just to witness a solar eclipse, and they often rack-up dozens of experiences. If the Moon-shadow is due to make land in a very specific area—such as over some small islands—a total solar eclipse can feel like a festival or a major sports event.

A solar eclipse is hectic, it lasts just a few minutes. It's blink-and-you've-missed-it stuff, and whether the inevitable clouds clear in time for totality can make it a stressful experience. It demands good research and preparation, and the ability to cope well with extreme disappointment. So stargazers make perfect eclipse-chasers!

Getting into Position

Scout-out a good location with a clear view of the entire eclipse. Use a stargazing app to fast-forward the sky and try to workout exactly where the Sun will be from First Contact until Fourth Contact.

An eclipse is a spectacle that moves through the sky, so a clear, open view is much better than peering through a gap between buildings. Avoid hills, and if you plan to watch from a beach, check if the eclipse coincides with a high tide that could force you to move inland.

Wherever you choose to watch the eclipse from, you're stuck there, so choose where you're going to be on the day before and get there early. Eclipse-chasing can be a nervy experience, and it's always emotional. If you miss totality because of cloud, it can also be an upsetting experience, especially if you've travelled across continents. However, it's best to be prepared for clouds to ruin everything, something that stargazers are well used to. It may feel like a poor second prize at the time, but the dramatic blackout that only a total solar eclipse offers is well worth the trip.

Photographing a Solar Eclipse

Witnessing a total solar eclipse is one of nature's rarest and most awesome events. It's natural to want to photograph it, but it's not an easy task. If you're traveling far, think about whether you will be happy to be fiddling with a camera during this rare and brief event. Most people who do try to photograph their first eclipse regret it and wished they'd spent more time looking at the totally eclipsed Sun, which for a few minutes is utterly captivating. Better wait until your second or third eclipse before you dive behind a viewfinder.

Looking directly at the Sun through the viewfinder of a DSLR camera is even more dangerous than with the naked eye. Use special solar eclipse viewing glasses regardless of your photography plans.

Although pure eclipse photography is strictly for DSLR cameras, a wide angle lens, compact camera or a smartphone can be used to capture atmospheric images of people watching the eclipse. The event is often as much about people as it is about viewing the Sun's corona, and the grand celestial mechanics.

For serious close-up shots of the partially and fully eclipsed Sun, only a DSLR camera and a telephoto lens on a tripod will do. A 600 mm lens is preferable, but use the longest lens you can get your hands on, and buy a 2× teleconverter to extend its reach. A solar filter or a strong neutral density filter will help prevent overexposure.

If your camera has a spot meter, meter on the Sun and use that exposure throughout the partial phases. The opacity of the sky will change if it gets cloudy, but it's a start. With a solar or neutral density filter in place, set your ISO to its lowest setting, and shoot in manual mode with an aperture of F8 and a fast shutter speed. If the Sun is overexposed, either use a faster shutter speed or smaller aperture and if it's underexposed, set a slower shutter speed or wider aperture.

Best of Both Worlds

If you are in two minds about photographing a total solar eclipse, consider shooting a video and extracting individual frames later. The Sun will

appear very small, but it's a neat way of getting a souvenir shot while also witnessing the event with your own eyes and emotions. You'll still need a tripod. It's also important to lock the exposure level to capture the changes in brightness (otherwise your camera will simply compensate for the lack of light and ruin the effect).

Either way, if you are going to photograph an eclipse, avoid crowds if you can; your tripod will get kicked, and people will likely walk in front of your camera.

Using a Smartphone and Binoculars

Using a smartphone or compact camera won't get you a professional photo of the eclipse, but great results are possible. It's also far cheaper and more casual than investing in DSLR cameras and telephoto lenses.

If the cloud cover is enough to take the edge from the Sun's brightness, a basic image of a smiley face Sun is possible using just a smartphone, though magnification helps enormously. This is where some basic stargazing gear comes in. If you have a pair of mounted binoculars, you can easily take a great snap through them with a smartphone or compact camera if there's some cloud cover (Fig. 14.7), but this can be risky; never look at the Sun through binoculars even with your safety glasses. With no cloud, a solar filter is needed for the binoculars (not the smartphone), which can be fashioned from a sheet of Mylar, or from welder's glass.

Holding a smartphone or compact camera behind a binocular eyepiece to take a photo isn't easy, but it is possible. Most smartphones and cameras have a timer option; a two-second delay on the shutter release helps enormously, especially if you have to press the touchscreen to take a photo, which causes a judder that will ruin your photo. To make things easier, binoculars mounts are now becoming available for smartphones, which greatly helps with stability, though the shutter delay remains important.

Fig. 14.7 It's possible to photograph a partially eclipsed Sun through cloud using just a smartphone and some mounted binoculars © Jamie Carter

The Next Total Solar Eclipses

The chances of seeing an eclipse with near certainty are rare; clouds are almost always a hazard. The closest to a sure thing will occur in August 2027 when a very long six minutes and 22 seconds of totality will occur over Luxor in Egypt at midday, where the chance of cloud is practically zero. Here's a rundown of upcoming total solar eclipses, and where the line of totality—also known as 'the stripes'—makes land (Table 14.1). However, most eclipses happen primarily at sea; cruise ships are often the best option, not least because they can maneuver away from cloud. Special flights above the clouds are the only sure-fire way of seeing totality, though you do lose the natural setting.

The Great American Eclipses

If you stand in one place on Earth for 100 years, you will, on average, see one total solar eclipse. However, just occasionally the law of averages

Table 14.1 Total solar eclipses 2016–2030[a]

Date	Viewing locations
March 8–9, 2016	Sumatra, Borneo, Sulawesi, North Maluku and Pacific Ocean
August 21, 2017	USA (Georgia, Idaho, Illinois, Kansas, Kentucky, Missouri, Nebraska, North Carolina, Oregon, South Carolina, Tennessee, Wyoming)
July 2, 2019	South Pacific Ocean, Chile and Argentina
December 14, 2020	South Pacific Ocean, Chile and Argentina
December 2021	Antarctica
April 8, 2024	Mexico, USA (Texas, Arkansas, Missouri, Illinois, Kentucky, Indiana, Ohio, New York and Vermont), Canada (Ontario, Quebec, New Brunswick and Newfoundland)
August 12, 2026	Iceland and Northern Spain (Valencia, Zaragosa, Palma and Bilbao)
August 2, 2027	Saudi Arabia, Yemen, Tunisia, Egypt
July 22, 2028	Australia (Wyndham, Kununurra, Tennant Creek, Birdsville, Bourke, Dubbo and Sydney), New Zealand (Dunedin)

[a]Dates from NASA Eclipse website (eclipse.gsfc.nasa.gov/eclipse.html) and www.timeanddate.com (http://www.timeanddate.com/eclipse)

breaks down; the town of Carbondale, Illinois in the USA will experience two blackouts in just seven years. Not only will the USA experience a total solar eclipse on August 21, 2017, but another will sweep through on April 8, 2024. While totality lasts just two minutes in 2017, it's over four minutes seven years later. Both eclipses have completely different paths, but they intersect near the Illinois, Missouri and Kentucky state border. Given that the last total solar eclipse in the USA was in 1979, these two events so close together represent something of a celestial jackpot.

Lunar Eclipses

By now you should have spotted Earth-shine on the Moon (Chap. 3), and you also know when to see a Moon-shadow. You can complete the set by finding an Earth-shadow on the Moon.

Fig. 14.8 These sequential photos show the Moon entering the Earth's penumbral shadow *bottom-left* and exiting its umbral shadow *top-right*. Credit: NASA

A total lunar eclipse is not as special as a total solar eclipse, but it is a much longer spectacle. Instead of one moment of wonder, totality during a lunar eclipse can last for well over an hour, while the Moon can take over five hours to enter and exit the Earth's shadow fully (Fig. 14.8). It's a subtle rather than spectacular sight, but beautiful nonetheless.

A lunar eclipse can only happen at Full Moon, when our satellite is at its dazzling brightest, but during the eclipse it doesn't just lose its illumination. Earth prevents the Sun's light from directly hitting the Moon, but some sunlight refracted through the Earth's atmosphere gives the lunar surface a dull, reddish orange or copper color. It's often called a Blood Moon, though that's a massive exaggeration. The science at play is the same as the reddening of a rising and setting Sun. No two lunar eclipses are identical, which make them very special events for Moon-watchers.

Types of Lunar Eclipses and Key Moments

A lunar eclipse of any kind is a very easy event to watch. It doesn't require special glasses to view it safely, and nor do you have to travel; a lunar eclipse of some kind will be visible from where you live typically every years, and sometimes more frequently.

Though a total lunar eclipse is the one to get excited about, there are a couple of other kinds of lunar eclipse that committed Moon-watchers won't want to miss. Because it's visible from vast swathes of the planet (anywhere on the night-side), from many locations the Moon will already be partially eclipsed as it rises or sets.

Penumbral Lunar Eclipse

Earth permanently throws a shadow into space, but around its edge the penumbral shadow is fuzzy and ill-defined. When the Sun, Earth and Moon are almost aligned, but not quite, the Moon passes through the penumbra and loses much of its brightness. It looks lifeless. If you ever wished the Full Moon was less bright so you could see the stars clearer, this is your chance, though most people don't even notice a penumbral lunar eclipse.

Partial Lunar Eclipse

Much like a penumbral lunar eclipse, the Moon passes into the Earth's outer shadow, but this time the Sun, Earth and Moon are almost precisely aligned. However, during a partial lunar eclipse only a portion of the Moon passes directly into the deepest part of Earth's shadow, the umbra. The spectacle begins and ends with a penumbral lunar eclipse, but halfway through it around half of the Moon gradually loses its illumination. That dark portion is, in fact, going copper and red, but the illuminated side of the Moon is still so bright that our eyes can't see the contrast. It's odd to suddenly see a half-lit Full Moon, though perhaps the weirdest sight is the division between light and dark. Instead of the long shadows being thrown across the curved terminator line on the surface during its regular phases,

Fig. 14.9 As the Moon enters the Earth's umbral shadow there is the odd sight of its disk half-illuminated, but with no sharply-defined terminator. Credit: NASA

there's a subtly curved, though fuzzy line dividing the un-lit and lit portions of the Moon. What you're seeing, rather incredibly, is the outline of the Earth on the Moon (Fig. 14.9).

Total Lunar Eclipse

Also called an umbral eclipse because the whole of the Moon fully enters the darkest part of Earth's shadow, a total lunar eclipse starts with a penumbral, then a partial lunar eclipse, losing all of its usual Full Moon brightness. As it begins to enter the dark umbral shadow of Earth, one edge begins to look a little orange, though not until the dark shadow has spread right across the lunar surface will it look completely colored (Fig. 14.10). This is totality, where Sun-light is being bent through the Earth's atmosphere and on to the Moon. Look out for deep pinks and

Fig. 14.10 Sunlight bent by the Earth's atmosphere causes an eclipsed Moon to appear crimson, pink or orange. Credit: NASA

oranges. After as much as an hour of totality (depending on how far into the umbra the Moon is passing) the process then reverses, with the color quickly receding as the Moon exits the Earth's umbra.

The Blood Moon

Usually it looks somewhere between pink, copper, rust, brown or simply dark grey, but the colors you can see during totality vary enormously. It all depends on what's going on in the Earth's atmosphere. For instance, volcanic eruptions that have thrown up ash in recent days and weeks can affect what the Moon looks like. If there is ash in the atmosphere, it can go even an even deeper shade of pink or orange than normal. There's no way of knowing in advance what color the Moon will be during totality, which is what makes a total lunar eclipse so enthralling for Moon-watchers.

The Moonless Milky Way

Dark skies are technically irrelevant if you want a good view of a lunar eclipse. You'll get just as good view in a busy city as in the middle of a desert or a national park, but that's not the whole story. Interrupting a bright Full Moon for a few hours, a total lunar eclipse can vastly improve the darkness of the night sky. If you find yourself in a dark sky destination be sure to take your eyes from the Moon and look for the Milky Way. It will have been drowned-out by Full Moon-light just hours before, but can be easily viewed during the eclipse, as can the previously washed-out stars.

Photographing a Lunar Eclipse

A lunar eclipse is much easier to photograph that a solar eclipse, but it is just as much about timing and positioning. The best photos tend to be landscape shots that capture a rising eclipsed Moon low on the horizon, though what you will see, and when, depends exactly where you are on the planet's surface. The easiest tactic is to use a telephoto lens or a telescope and just photograph the Moon's changing hues. Try autofocusing on the Moon itself using the LCD screen, then switch to manual focus and use masking tape to secure the lens. Set the camera at ISO 200 and the aperture to F11 and attempt exposures of 1/60 second down to 1/15 second, and even to one second. When the Moon is completely colored, experiment with four second exposures at ISO 800 and ISO 1600. Take a photo every 10 minutes and each one will show the Moon to be a slightly different color. You'll also get stars around the Moon, which are normally lost in the glare. Since the Full Moon will still be in the faint penumbra shadow of Earth well before and well after totality, it will be much dimmer than usual. It's therefore relatively simple to produce some unusual-looking photos of the Moon, and generally it's just easier to photograph.

A smartphone can be used for a wide-angle shot, too, though if you've got binoculars, prop them up or mount them on a tripod and try taking a photo through one of the eyepieces, as you can for the Moon (Chap. 10) or a partial eclipse through cloud (see above). The results are basic, but good enough for social media.

The Next Total Lunar Eclipses

Unless they come along in quick succession (as four of them did in 2014/2015 in the USA), lunar eclipses don't get much press (Table 14.2).

The Aurora Borealis (Northern Lights)

Sky watchers and stargazers alike love aurora. Visible as deep green curtains miles high suddenly radiating down, pulsing and rippling as if in a breeze, they dart across the night sky in totally natural, beautifully random

Table 14.2 Total Lunar Eclipses 2018–2030[a] (Locations given are for the total lunar eclipse phases; a partial lunar eclipse is visible for many more locations either side.)

Date	Viewing locations
January 31, 2018	Australia, New Zealand, South-East Asia, China, Japan, Russia, Alaska
July 27, 2018	Africa, Middle-East, India
January 21, 2019	North America, Central America, South America, UK, Scandinavia
May 26, 2021	Australia, New Zealand
May 16, 2022	North America, Central America, South America
November 8, 2022	New Zealand, Japan, China, Russia, North America
March 14, 2025	North America, Central America, South America
September 7, 2025	Middle East, China, India, South-East Asia, China, Australia
March 3, 2026	North America, Russia, China, Japan, Australia, New Zealand
December 31, 2028	New Zealand, Australia, Japan, Russia, North America
June 26, 2029	Central America, South America, West Africa
December 20, 2029	Europe, Africa, Middle East, Russia

[a]Dates from NASA Eclipse website (eclipse.gsfc.nasa.gov/eclipse.html) and www.timeanddate.com (http://www.timeanddate.com/eclipse)

ways. Aurora bands streaking across a clear night sky is most definitely one of stargazing's most intoxicating sights.

They may have little to do with stars and planets, but the aurora are a visible link to what's happening on the surface the Sun.

Silent Storms

When electrically charged particles from solar flares on the Sun's surface collide with atoms in the Earth's atmosphere, the result is often a light show of aurora around the planet's magnetic poles.

Most displays of aurora appear from the north (if in the northern hemisphere) as a faint green glow, which aurora hunters call a 'forest fire' (Fig. 14.11). On some nights, that's the peak of the displays. On other nights, the aurora spread overhead (Fig. 14.12) and an auroral storm consisting of curtains, arcs, swirls and streamers commences, and can last up to an hour. Within this silent

Fig. 14.11 Aurora are best used as a backdrop in photos. © Jamie Carter

Fig. 14.12 Magnetic auroral storms can appear suddenly and unpredictably. © Jamie Carter

storm there can be several distinct peaks and troughs of auroral activity. All of a sudden it will cease, with only faint shimmers visible in the distance until they fade from view. Though most auroral displays are green, it's also possible to see pinks, reds, browns, yellows and even blues.

The displays of aurora around the north pole and the south pole are identical. Dependent on exactly the same excess of particles from the Sun, the aurora borealis (Northern Lights) and aurora australis (Southern Lights) are almost a mirror image.

Observing the Aurora Borealis

The aurora borealis hit land far more often than the aurora australis, which have to be at their very strongest to be viewed in either New Zealand, Australia or at the tip of South America. Unless you're hanging around Antarctica, the aurora australis are rare to see.

Not so the aurora borealis, for which you need to be under the auroral oval around the north pole. It waxes and wanes in size, but is centered on the Arctic Circle between latitudes of about 65–72 degrees North. Finland, Iceland, Norway, Sweden, Greenland, Iceland, Alaska, Northern Canada and Siberia all frequently see the aurora borealis. Since these areas have long, dark winter days (and very long summer days), peak viewing time for the aurora borealis is November through March.

Observing Tips

Get yourself somewhere away from light pollution (avoiding a Full Moon) and be patient. Those around the Arctic Circle often see aurora borealis directly above them, but if you're further south, look to the northern horizon. Wherever you are, the top of a nearby mountain that doesn't overlook a town or city to the north, or somewhere with a wide-open northern horizon, is a good choice.

Though you're likely to be stargazing while you wait, a cafe or somewhere warm to retreat to nearby helps because you may have to wait a few hours. Also remember that even if there are strong displays of aurorae, if it's cloudy or raining you'll see nothing. Aurora viewing means being outside late at night in temperatures well below freezing, so dress appropriately.

Magnetic Midnight

Experienced aurora-hunters can predict when displays may happen. Though it does pay to have someone in the know leading your search for aurora, the rule of thumb is simple; an hour either side of 'magnetic midnight'. If you've not seen any aurora by 1 am, it's probably not going to happen. That's a bit of a relief if you're in freezing temperatures.

Photographing Aurora

With a DSLR camera, some simple techniques and some good luck, it's possible to get great photos of the aurora. Forget smartphone cameras, they're not sensitive enough.

Another great reason for taking photos of aurora is that a camera is much more sensitive and will pick-up traces of green and other colors that might be invisible to your eyes.

Ideally use a wide-angle 10–20 mm lens with fast aperture of between F1.4 and F3.5 to get as much of the sky and foreground in the shot as possible. Makes sure your lenses are clean, and remove any filters you might be using during the day. As for all night sky photography, a tripod is mandatory because you may need to open the shutter for as much as 30 seconds. Use a remote shutter release cable, or set a two second delay on the shutter release to get sharp images. Ramp-up the ISO to 1600 and experiment with shutter speeds from four seconds to a maximum of 25 seconds. The results will astound you and, as a bonus, you might get stars (Fig. 14.13).

Fig. 14.13 Auroral curtains photographed in Finnish Lapland, with the Pleiades visible in the center. © Jamie Carter

The biggest mistake most people make is that they don't know their cameras well enough to quickly change settings in the dark and cold. It's therefore a great idea to prepare in advance; switch-off the lights at home and spend time in darkness changing the shutter speed, the aperture and the ISO on your camera until it becomes second nature. The aurora waits for no-one, and a spectacular display can come and go while you're face-down in your camera trying to change settings. If you know your camera and it's set-up well, you can frame a shot, open the shutter and get back to enjoying the show.

However, composition is everything if you're to avoid photos that look like little more than green clouds. Use the aurora as a backdrop, not the subject of a photo, perhaps using the top of a hill, fell or mountain, a house, a lone tree or a forest, or a river or lake for reflections (Fig. 14.14).

As with all outdoor photography expeditions, bring plenty of SD cards, a red head-flashlight and a spare camera battery or two kept close to your body. It will likely be too cold for fingerless gloves, but thin gloves that enable you to operate the camera are essential. Wear thick mittens over the top.

The Solar Maximum

The Sun has a cycle that lasts roughly 11 years. At the peak of the solar maximum the Sun spits-out more electrons and protons as huge solar flares and coronal mass ejections. These are responsible for auroral displays. The bigger the flares headed towards Earth, the brighter and more frequent are the displays, and the Auroral Oval gets larger, so people in more southerly latitudes can see them. A solar maximum is historically when aurora are at their most frequent and spectacular.

However, predicting the solar maximum is difficult because although 11 years is the average cycle, it can vary between nine and 14 years. One way of working out where the Sun is in its cycle is to witness a total solar eclipse (see above). During totality the Sun's corona can be small and tightly bound to the surface, or flared and stretching away from the Sun. Either way, it can give you a clue to how fruitful your next search for aurora may be. The mid-2020s are expected to be the best bet for the next solar maximum, but as always in stargazing, there is no guarantee.

Fig. 14.14 An object in the foreground helps improve photos of the aurora, though patience is required. © Jamie Carter

CHAPTER 15

FINDING DARK SKIES

Why Travel?

Most people first notice the stars not from their own backyard, but when far from town and cities. With light pollution spreading, stargazers must head to rural locations. The rule of thumb is simple; when the Moon is down, go to wherever humans are not. How easy it is to find dark skies will depend on where you live. For some, just a short drive may suffice, but for many people, it means a 100-mile drive at least to properly escape light pollution (Fig. 15.1).

Most stargazers don't often experience dark skies, and don't know where to find them. Cue a network of Dark Sky Parks and Dark Sky Reserves across the planet that protect against light pollution and preserve the night sky. Such dark sky destinations should be on every stargazers' bucket list.

However, if you plan to travel-gaze, don't only visit sites designated by the International Dark-Sky Association (IDA). They're primarily aimed at preserving night skies in light polluted regions, such as the US and Europe. Few such parks exist in South America, Africa and Australia, where the dark skies above vast wilderness areas are not under threat. Hiking through the mountains of Peru or Chile, going on safari in Africa, or traveling into the remote Australian bush will guarantee you dark skies that rival any official Dark Sky Park.

Since we don't all see the same sky in either angle or clarity, observing in unfamiliar locations will also sharpen your stargazing skills. By changing your location on the planet you'll get a different orientation. Get closer to the equator, or even beyond it, and strange new stars, unfamiliar constellations and an odd-looking Moon will give you a completely new perspective on the night sky (Chap. 13) (Fig. 15.2).

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7_15

Fig. 15.1 Europe, the USA and Japan seem ablaze on this night view of the globe, but there are precious dark spots within. Credit: NASA Earth Observatory image by Robert Simmon, using Suomi NPP VIIRS data provided courtesy of Chris Elvidge (NOAA National Geophysical Data Centre)

Fig. 15.2 It's becoming increasingly necessary to travel to find truly dark skies. Credit: ESO/S. Brunier

The Bortle Dark-Sky Scale

How do you compare dark skies? At the darkest places on Earth on a Moonless night, the brightest section of the Milky Way—visible in Sagittarius (Chap. 8)—should cast a shadow. That's according to the Bortle Dark-Sky Scale, which rates nine different kinds of sky. It's the first four types stargazers should be looking for. A perfect Class 1 sky has a naked eye limiting magnitude of +7.6 and bright zodiacal light (Chap. 8). That's unlikely unless you're truly cut-off from civilization, but judging whether you're under a Class, 2, 3 or 4 sky is relatively simple. It's all down to the three million light years distant Triangulum galaxy, M33, which we observed before (Chap. 10).

Naked Eye Target: The Triangulum Galaxy, M33

If you can find M33 easily from where you are, the Bortle scale says you're under Class 2 skies. You'll see globular clusters, structure in the Milky Way and dark areas within it, such as the North American Nebula NGC 7000 (Chap. 8). The limiting magnitude is between +7.1 and +7.6 in Class 2 skies, but they're rare. If M33 is visible in the corner of your eyes only if you look to the side of it, it's a Class 3 sky that you're under, which should also offer you a stunning Milky Way, the occasional globular cluster like M7 (Chap. 7) and a limiting magnitude of between +6.6 and +7. Class 3 skies are your average rural skies, which usually include a small band of light pollution low on the horizon. Class 3 skies are the peak of most stargazing careers, and for any primarily urban stargazer, still hugely impressive. Get to Class 4 skies and M33 drops out of view as light pollution begins to dome-up in all directions, but +6 magnitude stars can be seen. If you're regularly stargazing under Class 4 skies, count yourself lucky.

The Impact of Darkness

The Bortle Dark-Sky Scale isn't definitive, and nor is it necessary to constantly hunt-down Class 1 skies. In terms of the impact a dark sky can have, you only need look for a small increase in visual magnitude; if you move from a light polluted city where you can see +4 magnitude stars to

somewhere away from the city where +6 magnitude stars can be seen, the difference will amaze you. There's so much more to see.

Things completely out of your control can ruin even a Class 1-rated dark sky site; snow is hugely reflective and amplifies light pollution intensely, while car headlights can dazzle you in an instant. The presence of a bright Moon also renders any dark sky comparisons pointless.

Gaining Altitude

There is, however, an easy way to cheat the Bortle Dark-Sky Scale; head upwards. Altitude can really bring out the clarity of the night sky, and when stargazing from a high mountain zone a Class 4 site can easily become a Class 3. The tell-tale is planets; at altitude a bright Jupiter or Venus can become almost as distracting as the Moon.

Heading East or West

If you live at, say, 40 degrees latitude North and you travel between the USA, northern Europe and East Asia, you'll notice almost no difference in the night sky. Constellations and stars will rise and set at similar times and places in the sky because you're not shifting your position in relation to the Earth's rotation.

Changing Your Latitude

Want to see the Milky Way's center? Head south in summer. By heading south towards the equator (perhaps to Florida, Mexico, the Canary Islands or North Africa) the constellations that can only be glimpsed on the horizon are suddenly high in the sky and much easier to see. Though they're easily visible below about 30 degrees North, the glittering jewels of Sagittarius and its Teapot asterism (Chap. 7) reveal themselves most clearly when they're high above and out of the haze of the southern horizon. Since Sagittarius passes directly overhead from June-September, the southern hemisphere gets the very best view.

What to Pack

Transporting a telescope across the world isn't practical. Amateur astronomers on dedicated dark sky trips will often pack tripods, finder-scopes, a couple of cameras and more besides. The majority of stargazers will visit a dark sky zone as part of a longer trip, especially if it's a long-haul destination, so traveling light is essential. It's also perfectly possible; pack only a pair of 10 × 42 or 10 × 50 binoculars, which fit nicely into a cabin-sized backpack. Also in your bag should be a printed star-chart, a flashlight with a red light mode and (perhaps most importantly of all) an observing list or a detailed idea of what you want to see and do when you get under the untainted night sky you may have traveled far to experience. Where you're going, what optical equipment you'll encounter, and who you'll be stargazing with will help decide that. Hopefully this book will also help you select some seasonal sights wherever in the world you visit.

Visiting Observatories

With well-equipped observatories dotted around the world's dark spots, there's little need to travel with a telescope.

Even if you've a big telescope at home, you'll not have anything approaching the size and quality of the gear regularly found at professional or even public observatories. Many of the world's very biggest telescopes responsible for the latest astronomical research are often robotic, unmanned and situated on remote mountainsides in Chile, Hawaii and South Africa, but they often don't want visitors. However, dotted around the globe are dozens of observatories committed to public outreach, small private observatories, stargazing-friendly hotels, and even campsites with telescopes. All offer superb night sky experiences. From guided stargazing and night walks to lectures and sessions with powerful telescopes, there are dozens of ways of interacting with both local people and the night sky in most of the world's greatest dark sky destinations.

Grand Canyon National Park, USA

Location: Arizona, USA

Latitude: 36 degrees North

Altitude: 6,800 ft/2,072 m

Best time to visit: September through November

Deep Time

The Grand Canyon represents deep time to rival anything visible in the night sky. With the naked eye we can see 2.5 million light years into history when we stargaze at the Andromeda galaxy (Chap. 10). The oldest of the 40 or so sedimentary rock layers visible at the Grand Canyon are a staggering two billion years old.

Geologists have come here since it was first protected in the 1890s, but now stargazers are flocking to this must-see national park for its lack of light pollution. "We're starting to see more and more people tell us that they're coming to the Grand Canyon for its night skies," says Ty Karlovitz, a Ranger who works in the interpretation division at Grand Canyon National Park, as we stand beside the south rim of the canyon at an altitude of 6,800 ft. "The Grand Canyon's night skies are one of my favorite parts of the job."

Dry Desert Air

The Grand Canyon doesn't have a particularly high reputation among amateur astronomers and astro-photographers, many of whom prefer the darker skies of the more remote national parks in southwest USA. Cedar Breaks National Monument in southern Utah, Arches National Park and Canyonlands National Park have the very darkest skies in the US, making southern Utah a dark sky destination in itself.

Fig. 15.3 Grand Canyon is aiming to become an International Dark Sky Park. Credit: Tyler Nordgren

However, Grand Canyon's popularity with stargazers has a lot to do with its location, its accessibility, and its altitude. "We've got a high elevation, dry desert air, and really clear night skies," says Ty, who tells me that the second half of September until mid-November is reliably clear. "In the early summer until early fall we have a dryer climate with no winter storms or summer rains, just crystal clear night skies." There's also about a million acres to stargaze from.

June brings the park's annual Grand Canyon Star Party; for eight days, amateur astronomers come from Tucson Amateur Astronomy Association and Lowell Observatory in Flagstaff to set-up telescopes behind the visitor's center for anyone to use, compete with talks, constellation tours and guided stargazing. On the north rim, the Saguaro Astronomy Club of Phoenix follows suit.

Light Pollution

This national park hasn't yet become a well known dark sky destination because there is some light pollution in Grand Canyon Village where most of the five million annual visitors either visit or stay. The park authorities are about to embark on a project to make lights more night sky-friendly. "The park does have a little light pollution, but we're working towards becoming an official Dark Sky Park," says Ty. "We're now using night-friendly colors for lights, like the softer oranges and reds," he says. Most of the lighting is already angled down, and nothing is projected up into the sky, though there is still work to be done in some of the main viewing areas on the south rim. "We're trying to make it better, but we have this natural setting that's really good—even in the Grand Canyon Village where the light pollution level is highest I can walk out to the edge of the canyon and look up and see a lot of really neat stuff."

Ty is right. During my chilly January visit I spotted Venus, and beside it tiny Mercury just after sunset, followed an hour later by the Milky Way. It was filling the sky near Perseus and Cassiopeia overhead, and tipping into the vast Winter Circle asterism (Chap. 2).

To see that, and the Beehive Cluster as an easy naked eye sight, needs only a short walk away from Grand Canyon Village down Bright Angel Trail.

For now, that works OK, though there are distant threats to any future Dark Sky Park status. "We do get a little bit of light pollution from big cities," says Ty. "If you look way off to the west you can see a faint glow from Las Vegas, but it's not enough to really inhibit the viewing of the stars."

Best Stargazing Spots

The modicum of light pollution does mean that it's best to drive for a short while east of Grand Canyon Village. A couple miles away, Mather Point makes a great observing sight if you're staying overnight in the area, though the remoter Desert View and Lipan Point on the south rim (about 20 miles drive from Grand Canyon Village) are even darker, and more secluded.

However, the very best view of the night sky is to be had simply by walking down into the Grand Canyon itself, and camping out. "The canyon walls will block the sky a little bit, but that can be a good thing because getting in the canyon can help to focus you," says Ty. "Typically you're looking almost straight up at the darkest part of the sky."

He tells me that he's taken many groups into the canyon who've never before left the city. "There are just so many stars, and the Milky Way as well, it's almost too much for them," he says, adding that he thinks stargazing is a great way to connect people from across the globe. "One of the neat things about the night sky is that it's something we all have a connection with. The Grand Canyon brings folks from right across the world, and when we look up at night and we see the stars, they're the same stars that rise on the other side of the planet."

Different Stories

If you travel to dark sky destinations, soon enough you begin to leave behind the constellations you've spent so much time learning. After all, what use are Greek myths when you're in the remote deserts of the Wild West? "I'm fascinated by the taking of the exact same group of stars to

make a totally different story. It all depends on our perspective and our backgrounds," says Ty, who recalls that while working in Honolulu National Monument in Hawaii he learned that the W-shape that makes Cassiopeia is known locally as the Chief Frigate Bird.

There have been humans in the Grand Canyon for 10,000 years, and in that time a few stories have built up. "We're all looking at the same constellations. When we look up and we see the Big Dipper and Cassiopeia, and the north star, for the Navajo in the Grand Canyon that was one giant constellation," he says. "The Big Dipper is Revolving Male, Cassiopeia is Revolving Female, and Polaris is the central fire." These circumpolar constellations represent the Navajo ideal; a husband and wife, with a cooking fire between them (Fig. 15.4). However, other Native Americans saw the same stars of Revolving Male both as a bear (just as the ancient Arabs had with Ursa Major) and as a skunk, its tail raised high behind it (Childrey 2004). The skunk shape is particularly convincing; Ursa Major will never look the same again!

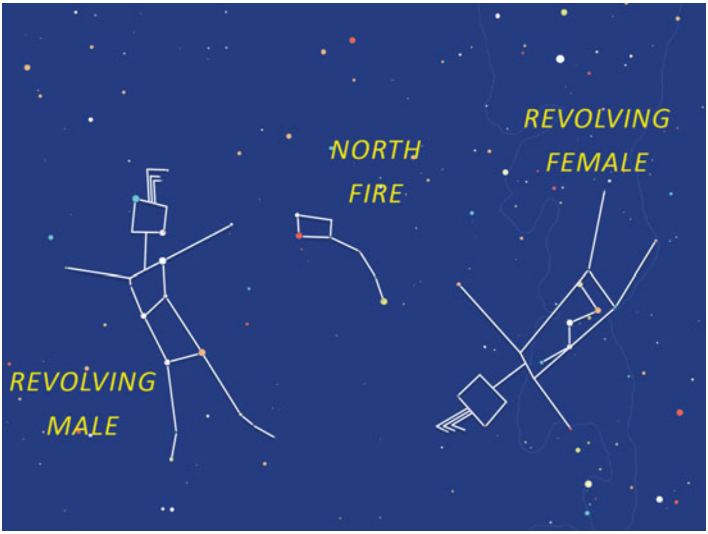

Fig. 15.4 The Navajo constellations of Revolving Male and Revolving Female around the North Fire (based on two illustrations in Childrey 2004)

Navajo Constellations

Most of the Navajo stories tend to relate to the circumpolar constellations and the winter stars. "Orion is another ideal male figure, a young warrior, a hunter and a provider," explains Ty. "Like so many other cultures, they tie that in with Scorpius, since the two are always opposite each other in the sky. For the Navajo, Scorpius is basically the mother in law."

How ancient cultures used the stars to tell stories is called archeo-astronomy, a subject that's popular among stargazers and far less so among astronomers. For Ty, it's the main reason to gaze at the stars while he travels around this two billion year old park. "The stars are just a neat way to go back in time," he says.

Parque Nacional del Teide, Tenerife

Location: Tenerife, Canary Islands, Spain

Latitude: 28 degrees North

Altitude: 12,198 ft/3,718 m

Best time to visit: August through October

Just 60 miles from the coast of Africa, the Canary Islands have a legendary reputation among stargazers. They have four of the ingredients all dark sky-seekers in the northern hemisphere are looking for; reliably clear and dark skies, high altitude, and an enviable position near to the equator.

Year-round mild temperatures make the likes of Gran Canaria, Fuerteventura, Lanzarote and La Palma favorites among Europeans looking for winter sun. All are great for stargazers, but one island in particular stands-out. On Tenerife you can enjoy some of the best stargazing conditions the world has to offer, witness a stunning sunrise from the top of an active volcano, and be back on the beach for breakfast.

Prime Position

Tenerife is a favorite destination for stargazers after an unrivaled view of one of the year's finest night sights, the Perseids meteor shower, which happens in mid-August every year (Chap. 8). It's also in prime position for the equatorial constellations. Here, at a latitude of 28 degrees North of the equator (which is about the same as Florida and Texas), it's possible in summer to see constellations like Sagittarius, Scorpius and Libra much more clearly than anywhere in Western Europe.

However, Tenerife's popularity with amateur astronomers had always perplexed me because the island attracts five million tourists every year. Sunseekers from all over Europe and beyond pile into the island year-round, and its main tourist town of Los Christianos is a big light polluter. In fact, coastal resort towns create an orangey glow that rings the island. How can this be a good place for dark skies?

But it is. The key is the altitude of El Teide, a 12,198 ft-high volcanic peak in the very center of the island. This is the highest point not only in Tenerife, but in all of Spain, and it rises from the vast Moon-like Parque Nacional del Teide, which is itself 7,729 ft above sea level. This UNESCO World Heritage Site is beloved of stargazers. Crucially, it's surrounded by an ancient caldera whose rocky ridges mostly block-out the light pollution from the south and west of the island. To the north, the town of Puerto de la Cruz can sometimes be glimpsed, but that coast is regularly covered by cloud. It's precisely that cloud that blocks-out the light, and makes stargazing from El Teide so reliably enthralling.

Sunrise Trek

Getting to the peak of El Teide isn't difficult. Hundreds of tourists drive the hour so from the coastal resorts every single day to climb into the telerifico cable car. It takes eight minutes to ascend to a viewing platform at a heady 11,663 ft altitude, with an optional 30 minute hike up steep steps to the summit. However, the last cable car back down leaves before 5 pm. There is only one way to see the stars from the mountain, and that's to spend the night.

A voucher for a bunk-bed in the tiny Refuge Altavista on the eastern slopes of El Teide can be booked online and includes a return ticket on the cable car. The tickets are sold separately because most of those planning to stay on El Teide hike all the way up from the base of the mountain, and intend to rise in the small hours to reach the summit. For my visit on a crisp, clear March day, I cheated and took the cable car up, knowing that I would be up very late stargazing. It was starting to get cold even before I stepped out of the cable car into thin mountain air. At the top, the volcanic rock was covered in snow, and so was the peak of El Teide just above.

But where was the Refuge Altavista? Unfortunately for those of us who didn't look at a map, it's actually about an hour's walk back down the eastern slope of the mountain. In the snow and ice of March, it took me almost an hour and a half (walking boots are essential, and walking poles would have been handy), but by 5 pm I was watching the shadow of El Teide—a classic pointed volcanic peak (Fig. 15.5)—stretch further and further in

Fig. 15.5 At over 12,000 ft up, the peak of El Teide (shown here as a shadow during sunset) is far higher than even the Observatorio del Teide (on the left of the image). © Gill Carter

Fig. 15.6 A star-trail from the Refuge Altavista, El Teide. © Gill Carter

front of me as the Sun set behind it. The shadow gradually coved the domes of the Observatorio del Teide, a working astronomical observatory 2,854 ft below. I felt privileged; from up here, the view was even better than for the professional astronomers (Fig. 15.6).

Transparent Sky

Refuge Altavista is above the clouds, and a magical place to be in darkness. During my visit there was a lot of snow on the ground, which is normally a big hazard for dark skies; even the merest drop of ambient light can be reflected skywards. However, here there was no light, except for the flash-lights of hikers coming down from the peak to find their bed for the night. By 9 pm, everyone else had gone to bed.

By then I was already outside; I noticed the hum of chatter disappear as I stood in awe at the clarity of the night sky. From my east-facing ledge near

to the Refuge, Orion was glowing more intensely than I had ever seen before, with the Pleiades living up to its name, and then some; I could count ten stars in the Seven Sisters.

Not a Sparkle in Sight

That night even faint constellations I had never seen before were almost too obvious. I was confused and had to check my star-chart; Cancer and Coma Berenices were easy naked eye objects, and so too was the Beehive Cluster, something I had strained to see in urban skies. A bright misty patch to the naked eye under such dark conditions, in my binoculars I could see well over 50 stars.

Then I noticed it. Up here, the stars weren't twinkling. They were completely still. Here, 3,718 m up, I was stargazing well above the thickets part of the Earth's atmosphere, higher than the clouds. Between the stars and I there was nothing. Just space.

Ecliptic on a Plate

I eventually crept into a creaky bunk way after midnight, the freezing conditions having driven me inside despite the stargazing treats above. Just a few hours later, I was up and dressed as the Refuge emptied out; for everyone here but me the main attraction was a 4 am trek up to the peak of El Teide to see a sunrise. The first hour required a powerful flashlight. Climbing through craggy, icy-covered lava is not easy. Just short of the peak in the scattering light of dawn the entire ecliptic was in full view. In the east, above the clouds was Venus, shining brightly, and the tiny, dimly-lit red dot of Mercury. It was red not because of the planet's color, but because I was looking at it through the Earth's atmosphere (much like a sunset). To the west I could see Mars and Saturn. With these planets visibly strung-out in a line just before sunrise, the ecliptic really made sense.

To see the plane of the solar system in full view is a good feeling, but just as good is the hot air spewing from vents at the top of El Teide, which I reached just before an orange Sun peaked above the clouds

The Lazy Way

Stargazing from the slopes of El Teide is unbeatable, but you'll get the same clarity from anywhere within the national park. Driving in from one of the coastal resorts for an evening's stargazing is perfectly possible (though the permanently cloudy northern coast is best avoided). There are lots of places to park the car, and almost any of them are wonderful places for astro-photography as well as stargazing.

At 10,000 ft altitude and with dark skies, Parque Nacional del Teide is one of the most impressive and accessible stargazing destinations in Europe. It's also the perfect place for a family holiday, so great for secret stargazers after a way to feed their habit while traveling with a family who have other priorities.

Observatoire du Pic du Midi, France

Location: Pyrenees, France

Latitude: 42 degrees North

Altitude: 9,440 ft/2,877 m

Best time to visit: September through November

It might be highest mountain in Western Europe, but Mont Blanc in the Alps comes a poor second for stargazers with a taste for the noir. The Observatoire du Pic du Midi de Bigorre, the most famous observatory in France, sits on top of a mountain top at a heady 9,440 ft above sea level. Surrounded by a huge International Dark Sky Reserve, it has a stupendous view of the night sky. NASA used this sight to make detailed maps of the Moon prior to the Apollo missions of the 1960s, and for well over 135 years astronomers have been lugging their equipment up to the peak to make observations. Now it was my turn.

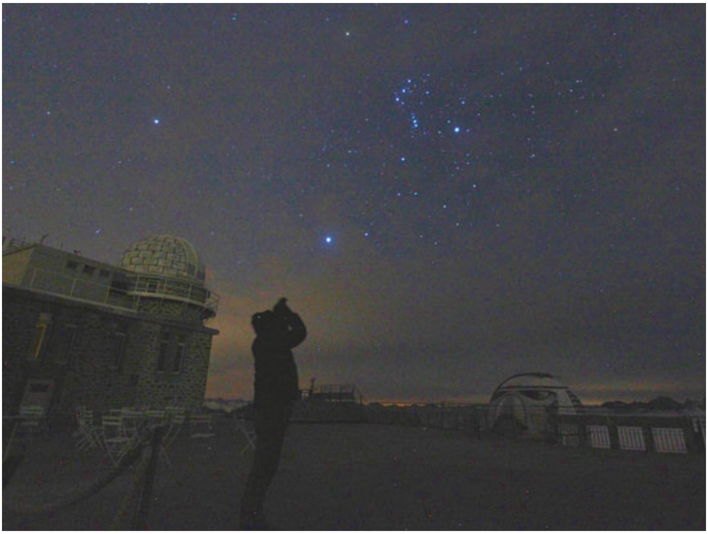

Fig. 15.7 Pic du Midi is surrounded by an International Dark Sky Reserve © Gill Carter

Journey to the Stars

"Fall is the best time of year to visit," says Jérome Brun, Director of Marketing at Pic du Midi, who meets me in the Haute-Pyrenees village of La Mongie in the south of France to start my journey to the Nuit Au Sommet (Nights At The Summit), a package offered by the observatory. "There's a special pureness to the air at this time of year, but in the winter season it completely changes because this is a high mountain zone," he adds.

Getting to Pic du Midi is half the fun. If the weather holds and there's no engineering works, a cable car will whisk you (plus water, food, astronomers and extreme skiers) up from the ski resort town of La Mongie to the peak in 15 minutes. The panoramas are exquisite as you ascend a kilometer, arriving inside the Observatory beside a gift shop and a restaurant. At least, that's what they tell me. Unfortunately, on my visit the cable car was being re-painted in readiness for the upcoming ski season. It was back to basics. The old mountain road beckoned.

The High Road

From the construction of the first dome in 1908 until the cable came into existence in 1952, astronomers at Pic du Midi had to hike up. It must have been a punishing trek. The drive up is nothing in comparison, but it's slow, the road narrow and precarious. There are steep switchbacks and fallen debris all over the road as we gradually drive into the clouds and out the other side. "It's going to be cloudy tonight but get up early around 5 am and it will be clear," says Jerome. Just before the peak I get out of the car and climb onto a funicular platform, which soon rises slowly up to the observatory itself. Above me is what looks like a giant ice-cream cone.

Telescopes with Altitude

At one end of the facility is the 90 ft-tall, cone-like Telescope Bernard Lyot (TBL), an 80-inch Schmidt-Cassegrain telescope that has been here since 1980. France's largest telescope, it's the main reason why Pic du Midi is still a working observatory despite the domination of both space telescopes and the giant computerized telescopes of South America. It's so powerful that it could read the time on the clock face of Big Ben, 826 miles away in London, if it wasn't for the curvature of the Earth's surface. TBL's two-meter mirror and 100 ft-long casing have been used to study distant galaxies, such as Andromeda (Chap. 10), and more recently to reveal the magnetic fields around stars, including Vega.

As well as an ice cream, Pic du Midi has both an igloo and a Stormtrooper from *Star Wars*. The product of French alfresco artists at 65ERS Graffiti, an igloo is painted on the T60 dome, which houses the observatory's one-meter Gentili telescope that was first installed by NASA in 1963 to map the Moon. It's now routinely pointed at the Sun and planets. Firmly on the dark side in more ways than one, the T1M dome–which is painted as a Stormtrooper's helmet–has a 12-inch Meade LX200R telescope that can be used by amateur astronomers. Standing at the terrace's entrance, the domes give an edgy look to this most isolated of places.

Cold War Relic

Walking the tunnels and corridors between the telescope rooms amid thick concrete walls and freezing conditions, Pic du Midi feels like a relic of Cold War. A substantial portion of the ridge is even occupied by the French military, and is completely out of bounds to tourists.

Despite its toy box of telescopes, the real attraction for stargazers is the huge terrace's panoramic views across the French Pyrenees. Though the west is partially blocked by the TBL, low horizons to the north, east and south make it a particularly good place for watching rising constellations and sunrises. An International Dark Sky Reserve, the surrounding Pyrenees National Park is 380 square miles and almost completely dark; just a few solitary lights are viewable among the mountains. There are actually 251 communities within the reserve, 72 % of which is above 6,500 ft. This core area contains no permanent lights whatsoever.

Nuit Au Sommet

No wonder, then, that the Pid du Midi regularly hosts its *Nuit Au Sommet* package that begins with five-star cuisine and finishes with a 5,000-star observing session. As always, such promises must come with the provision 'clear skies allowing', and sadly while I was on Pic du Midi the clouds refused to budge. A cosy night indoors in the modern and simple bedrooms in the Antares Quarter beckoned for most of the guests, but committed stargazing requires a lax approach to bedtime. By 5 am I was awake, wrapped-up warm and out on the terrace in the hope of clear September skies. The seeing (Chap. 10) wasn't great, but such is the clarity at this altitude that I was greeted with a stunning sight; the winter constellations out in force, and beaming as best they could through the haze. In the eastern sky the Orion Nebula shone beneath the belt stars while Sirius and Jupiter dazzled, and the Pleiades poked through the clouds.

Summer was over and I hadn't see these stars for six months; it was like being back with old friends. Fast-forwarding the sky is the best reason there is for getting up early (Chap. 3). While I watched, shivering, from Pic du Midi as a deep orange Venus appear momentarily on the horizon as the Sun rose, I was reminded of two of the pillars of stargazing. Wherever you are, never take clear skies for granted—and never give up on finding a gap among the clouds.

Cosmos Centre and Observatory, Australia

Location: Charleville, Queensland, Australia

Latitude: 26 degrees South

Altitude: 995 ft/303 m

Best time to visit: April-October

"Turn that thing off, we don't allow them out here." I start to make an excuse about stargazing apps, but it's too late. Jane Morgan, manager of the Cosmos Observatory, has marched ahead of me to prepare for the nightly public stargazing session. I'm not arguing with an astronomer; my smartphone goes back into my pocket, and it's staying there. This is the Australian Outback. This is a darkness that deserves respect.

Deep in the bush over 450 miles west of Brisbane across the Great Dividing Range, the country town of Charleville is where the vast Outback really begins. It's also home to one of the most charming and accessible public observatories in the world.

From Grey to Black

Nowadays Charleville is a popular stop for so-called grey nomads, the fleets of Australian retirees who hit the open road for months at a time to see their own vast country. There are three things for them to do in Charleville; visit the Royal Flying Doctors museum, see endangered rabbit-eared marsupials called bilbies, and spend time with the stars. Tonight, almost every visitor in town has chosen the latter. Dozens of people are waiting patiently for dusk inside the Cosmos Observatory, about a mile outside town near the airport, sipping a Light Year Latte, Cosmic Cappuccino or Saturn-Shire Tea in the deliciously themed cafe. The tables all contain laminated star-charts, the cookie jars store Big Bang Biscuits, and the display cabinets contain some of the most ancient meteorites ever found, here in the Australian bush.

Fig. 15.8 With just 39 cloudy nights each year and a range of powerful telescopes, the Cosmos Centre & Observatory in Charleville, Queensland is an ideal place to get to know the southern night sky. Credit: Cosmos Centre

Rolling Off the Roof

After coffee, cake and constellations, the observatory session begins and we all file outside onto red-lit paths that lead into a small building. We sit in chairs around the edge. Jane and her assistants then begin to talk about the night sky, what we should expect to see, and why stars are different colors (Chap. 2). Jane mentions house rule number one; no smartphones or any other white lights, but I have no idea if she's looking at me. It's far too dark to see anything in here. It then dawns on me why we've all been sitting in the shadows for 15 minutes; our night vision is being nurtured. The entire roof is then rolled off to reveal the four things I've traveled thousands of miles to see; the night sky above the Australian Outback, and a fleet of three motorized Meade LX200 GPS 12-inch telescopes. It's a magnificent sight.

Night's Window

For anyone from the northern hemisphere, standing on the fabulous outdoor observing platform at the Cosmos Observatory is a rare treat, but it's initially disorientating. I'm here in March, fall in Australia, and with night's window open I look across the bush at the southern horizon. I see nothing I recognize at first glance. Over the next few minutes we're shown the famous Southern Cross, the False Cross above it, and the Pointer Stars—one of them Alpha Centauri, our nearest neighbor—just visible in the south. If that's special treat, it's also a relief to be shown familiar Sirius above our heads and, nearby, two familiar, but odd-looking constellations that on second glance are an upside-down Orion and Taurus. Below it to the south is bright Canopus, a common sight in these parts, but completely unknown to me. Nearby are the Large and Small Magellanic Clouds, two naked eye dwarf galaxies to rival the Andromeda galaxy. The southern sky is already charming me, and that's without even having looked through a telescope yet.

Into Eternity

Leo and Virgo are climbing in the north-east, and tonight both contain interlopers, Mars and Saturn. At last it's time for a close-up, and the three motorized telescopes move in sync to point at Saturn close to the horizon.

Fig. 15.9 Stargazers with a Sun-scope have no need for darkness. © Jamie Carter

We visit a telescope in turn and see its rings, a glorious sight and proof that for some night sky objects, magnification is everything. However, after a quick look at Mars, it's time to see some of the sparkling sights only visible from the south (Chap. 13). First into the telescopes goes the fabulous Jewel Box Cluster in the Southern Cross, an open cluster of over 100 red, white and blue stars that in a telescope truly lives up to its name. Next up is Omega Centauri, a 12 billion year-old globular cluster. Looking at its several hundred stars really does feel like looking into eternity (Fig. 15.9).

Sun Viewing

By morning it's time for stargazing of a completely different kind. I'm back on the observing platform looking through one of the same telescopes, but this time it's fitted with a solar filter. Blessed with such reliably sunny weather, Sun viewing sessions like this one are a daily event at the Cosmos Observatory. I had never looked at the Sun close-up before, and it's a

stunning sight; the disk is exceptionally well defined, and it's fizzing with activity. Today is a particularly good session, with at least ten black areas visible on the surface, sunspots caused by magnetic field lines becoming twisted. I'm here at solar maximum, the peak of sunspots during the Sun's roughly 11-year cycle. This is when sunspots can lead to more solar flares and coronal mass ejections that are responsible for sending superheated X-class flares of plasma particles on a two-day journey towards Earth. The result is the green aurora that appears in the night sky above the north and south poles (Chap. 14).

Space Tourism

The aurora is for another trip, and so is my next close-up of the Sun (Chap. 14). As I'm about to fly back to Brisbane, a local journalist stops me and takes my photo; the resulting story in the Western Times newspaper with the title 'International Space Tourist spots the Sun' makes me smile, but it's increasingly what myself and many others are doing. With light pollution rampant in the northern hemisphere, traveling across the world specifically to look away from it is fast becoming essential for anyone after a clear view of the cosmos. For stargazers, it's the night skies from the Australian Outback that grab all the headlines.

Flagstaff Dark Sky City, USA

Location: Arizona, USA

Latitude: 35 degrees north

Altitude: 7,000 feet/2,130 m

Best time to visit: September through November

The mighty Route 66 cuts through Flagstaff, Arizona, but for many this small town is the destination. Arizona is well known for its dark rural skies, but up here on the Colorado Plateau both geography and history have helped shape something of a stargazer's theme park.

Fig. 15.10 Sirius and Orion above Lowell Observatory's Clark Telescope Dome. Its close proximity to Flagstaff has helped the town keep its night skies dark. © Jamie Carter

The 70,000 residents call their college town Flag, which is rather fitting since the town is a marker for everything a stargazer needs. Perhaps most important is altitude. At 7,000 feet (2,130 m), there's little moisture up here, and the seeing is good; there are around 250 clear nights each year.

The altitude and the unbeatable clarity of the skies in Flag is why, in 1894, Percival Lowell decided to build an observatory on what became known as Mars Hill. In the years after Lowell Observatory's construction the town appeared, nominally to serve astronomers and loggers of the surrounding Ponderosa Pine, vast forests of which stretch from Flag in all directions.

Lighting Ordinance

Flag has darker skies than towns a fraction its size, but not because of geography. Brightly-lit billboards along highways are conspicuous by their absence, gas station forecourts have canopies to restrict sky-glow, and all the streetlights have shielded, low pressure sodium bulbs. "We were the first town to adopt laws to try to protect the night sky," says Chris Luginbuhl at Flagstaff Dark Skies Coalition, a retired astronomer from the near by US Naval Observatory and something of a stargazing aficionado (Chap. 3). Since then Flagstaff has become a model for how to keep urban skies dark. Chris and his colleagues proposed the idea of the town becoming a Dark Sky City back in 2001, a concept that didn't exist at that time. It was then ratified by the Tucson-based International Dark Sky Association, the same body that's responsible for certifying the Dark Sky Parks, Reserves and Discovery Sites now slowly spreading across the planet. "We created the idea of a Dark Sky City, and we did it to help spread awareness throughout the community," says Chris, who insists that nobody is going to protect things they're not aware of, and that dark skies are for everyone to enjoy. "To say that the night sky is only for astronomers is like saying that the Grand Canyon is only for geologists," he says. He's right, though Flag's historic lighting restrictions do have much to do with the close position of Lowell Observatory.

Nightly News

Though Percival Lowell himself was obsessed by Mars, its was the discovery of Pluto by Clive Tombaugh in 1930 from Lowell's observatory that

made the headlines. Old habits die hard in Flag. The day I arrived in January 2015 the front page of the local *Daily Sun* newspaper held a report on an ugly massacre in Paris, just as all the national newspapers did, but it wasn't the top story. That privilege went to a report on how stars are more accurately being aged by a group of astronomers, one of them a former employee at Lowell Observatory. "It's probably the only town in America where astronomy makes the headlines," says Gordon Watkins, the owner of my lodgings in Flag, the Inn at 410. "It's always big news here." The historic house is just two blocks north of Flag's central Heritage Square, but even this close to the town's bars, hotels and businesses, after dark there are way more stars than streetlights.

The grip that astronomy has on Flag is obvious, nowhere more so that at the Inn at 410 itself. Original photography of the Moon, Saturn's rings, the Orion Nebula, Comet Hale-Bop from back in 1997, and several galaxies adorn the walls of the Observatory Suite. *Skywatching* by David H Levy and *The Friendly Guide To The Universe* by Nancy Hathaway sit by the bed-side table where you might normally expect to find a Gideon's bible. Above the bed are stunning photographs of an eclipsed Sun.

If the Observatory Suite is unique, it's not unexpected in a town with astronomy woven into its heart. Over at the visitor's center, housed in a 1926 railroad station (Amtrak still rumbles through here twice a day on its way from Chicago to Los Angeles), a dark skies-themed corner section sells t-shirts adorned with Hubble's deep sky photography, alongside constellation playing cards and stargazing field guides.

The Pluto Roll

There are other novelties, such as Dark Sky beer and a Starlight Inn, the latter of which harks back to Flag's nickname at the start of the twentieth century, Starlight City. However, 2015 sees a new tribute to Lowell Observatory's pivotal place in the discovery of Pluto, and in the New Horizons mission to photograph it close-up for the first time. To help mark Lowell Observatory's Year of Pluto, Karma Sushi down on Route 66 was serving-up the Pluto Roll—tempura lobster with snow crab—with a dot of puree on top to represent the dwarf planet.

It may be fashioned from rice and seafood in Japanese style, but this tribute contains some historical accuracy. Legend has it that around 4 pm on February 18, 1930, observing assistant Clive Tombaugh found tiny Pluto from a distance of 3 billion miles (or 32 AU, Chap. 7) on the photographic plates he'd exposed the night before. He found it after lunch, making it the only planet to be found in daylight. Tombaugh had just eaten lunch at the Black Cat Café in Flag, the present home of Karma Sushi.

Universe in Green

But I'm not in Flag just for lunch. The public stargazing sessions that take place in front of Lowell Observatory's historic Rotunda each night from dusk are fast becoming legendary among stargazers.

However, before it gets dark I get a renewed sense of the scale of the cosmos just by walking through the pine forest on Mars Hill. The Galaxy Walk starts with the Sun and finishes at the galactic center some 500 ft (and 30,000 light years) later. Using a scale of around an inch to five light years, the solar system is passed after a tenth the width of a human hair. First comes the solar neighborhood, from Proxima Centauri (Chap. 13) to Sirius, to Vega to Arcturus 37 light years distant, then the Pleiades and other open clusters at 440 light years. Then comes star-forming regions like the Orion Nebula 1,270 light years and the truly colossal star Deneb (Chap. 6), and ten times further, globular clusters. It ends at an innocent-looking forest clearing that doubles as a supermassive black hole. The path takes about 10 minutes to walk, which equates to a speed of about one billion times the speed of light. The nearby Universe Walk—where the scale is upped to two million light years per inch just to fit it on the planet, never mind on Mars Hill—is equally staggering.

On a much more manageable scale (a mere one million miles per inch), the Pluto Walk proves just as eye-opening. It leads from the main buildings to the aptly-named Pluto Telescope Dome (Fig. 15.11) where Tombaugh discovered the then-ninth planet, but alongside are the relative positions of the planets; Mercury, Venus, Earth and Mars are all passed by after only a few steps. It's then quite a march to Jupiter and Saturn before a long gap to Neptune, Uranus and, finally, to Pluto. The latter's dedication is somewhat poignant. Its interpretation sign stands not 15 yards from where it was discovered. It's jokingly referred to as Pluto's gravestone (Fig. 15.11).

Fig. 15.11 The Pluto telescope with the dwarf planet's 'gravestone' beside. © Jamie Carter

A Comet Close-up

Since its orbit of the Sun is a staggering 248 years, Pluto won't be up in January until 2065, though it's never an easy or impressive telescopic object. Luckily, there are many more solar system objects to see during my two evenings up on Mars Hill. An experienced and friendly team of volunteers man the 12-inch and 16-inch Dobsonian telescopes (Fig. 15.12), one of which is focused on Comet Lovejoy. By lucky chance it's near the zenith and as bright as it will ever get during the week of my visit. If seeing it both naked eye and close-up was a treat, so was tracking its swift movement through Taurus to close to the Pleiades over just a couple of nights. There followed an hour in the McAllister Dome with Jupiter in the way of a 16-inch telescope. As well as identifying seven of its atmospheric bands, I glimpsed the shadow of one of the Galilean moons (Chap. 11) as it crossed the giant planet's disc. Talk about good timing.

Fig. 15.12 A 16-inch Dobsonian telescope is used each night for public stargazing at Lowell Observatory. © Jamie Carter

Year of Pluto

The next day I go back to Mars Hill to meet Jeff Hall, the Director of Lowell Observatory, who during my visit is all-consumed by New Horizons' imminent Pluto flyby. I put it to him that Pluto's relegation to a dwarf planet by the International Astronomical Union (IAU) in 2006 must have been hard to take for Lowell Observatory, and for Flagstaff generally. He shrugs it off. "Personally I like the simplest possible definition of a planet, which is: it's a ball, which means it's round as a result of its own gravity, and it's not a star, it doesn't shine," says Hall. "That omits not only Pluto, but a whole slew of things not just in the solar system, but around other stars that we're finding. By the current definition of planets, you can't call them planets. It seems to me to be scientifically a very narrow definition." The IAU has since decided that dwarf planets are special kinds of Trans-Neptunian Objects that deserve their own name; Plutoids.

Even if Pluto is considered a Kuiper Belt Object (Chap. 8) rather than a planet, Lowell Observatory is still committed to the former planet in its research. "The Kuiper Belt is a very interesting region in its own right—we're not shying away from the 'is it a planet?' debate," says Jeff, who leads a team of astronomers who are now studying Kuiper Belt Objects as well as looking for new exoplanets. "In 1930 we discovered a world here at Lowell, and now we are very heavily into discovering other worlds around other stars," he says.

The View from Mars Hill

Hunting for new worlds is something you can no longer do from Mars Hill. Standing next to Lowell Observatory's historic Clark Telescope, from where Vesto Slipher's research revealed that the Universe is expanding, the Milky Way looks clear and bright, though only to the west, away from Flagstaff below. Look east and the headlights from cars on Route 66 are obvious, though block-out the 'mother road' with even an outstretched finger and Flagstaff truly looks like the Dark Sky City it claims to be. "The Flagstaff lighting ordinance is dramatic," says Jeff, who shows me an all-sky image taken halfway between Winslow, population 10,000, and the 70,000-strong

Flagstaff. Winslow looks far brighter. “Flagstaff is doing very well indeed,” he says, yet since 2012, Jeff and his colleagues have been using the 4.3-meter Discovery Channel Telescope, an enormous structure constructed in remote forests at Happy Jack, about 40 miles to the south of Flag at a breathless 8000 ft. “Even with the world’s best dark sky ordinance you would never build a 4.3 meter telescope right next to a city of 70,000 people—it just wouldn’t make sense,” he says.

The Gift of the Night

Flag’s Dark Sky City status isn’t for astronomers; the gift of the night is for stargazers. Don’t confuse Dark Sky Cities and Communities with Dark Sky Parks, where light pollution is virtually banned. Dark Sky Communities are designed only to reduce light pollution, or slow its growth; Flagstaff will always be a bright spot on the map compared with nearby national parks and wilderness areas. “The Dark Sky Communities are darker than your average community, but that’s all they are—it still might have a pretty bright sky depending on population density,” says Chris. “Flagstaff is about 25 percent darker that your average town.” Other Dark Sky Communities—all in the USA—include Beverly Shores in Indiana, Dripping Springs in Texas, and Sedona, just 30 miles south of Flagstaff.

Lighting Zones

Mars Hill won’t ever get new telescopes on the scale of the Discovery Channel Telescope, though astronomy does still thrive around Flag. The town’s lighting zones, which restrict the level of lumens that can be emitted per acre, are keeping a hill just outside the city limits dark enough for astronomy. Lowell Observatory has four telescopes on Anderson Mesa while the US Naval Observatory has built an optical interferometer. “They’re preparing to upgrade that with four more 1.8 m telescopes, at which point it will be the most sensitive instrument of its type in the world, bar none—and it’s just nine miles from a city of 70,000 people,” says Hall. “That they’re still willing to do that says a lot about Flagstaff’s lighting ordinance.”

The LED Threat

For how much longer astronomers and stargazers can enjoy the night sky over Flag depends not on the town's history, but what happens next. In towns and cities across the world there's a buzz of excitement about LEDs, which promise low-cost street-lighting. For the night skies, however, LED comes with a high price; sky-glow of a kind that's hugely damaging to astronomical observations, and night sky visibility generally. "When you switch from low or high pressure sodium to white light, the sky will brighten three times," says Chris, who laments that filtered versions (FLEDs) are neither yet bright enough nor economically viable. "FLEDs are not the ones with the research and marketing power behind them, it's all white LED," says Chris. It's also possible that research into the negative effect of white LEDs on insects and nocturnal wildlife could mean they too need replacing in the near future.

Precious Legacy

No stargazer could fail to love Flag. Lowell Observatory is a fabulous place to visit and the Flagstaff Dark Skies Coalition's pioneering work on lighting ordinance is inspiring. A progressive town where constant pressure on policy-makers by passionate people is having dramatic results, Flagstaff is nevertheless not supposed to be a dark sky destination.

Wherever there are humans, there is light, and more of it each year; the legacy of the Flagstaff Dark Skies Coalition won't be a city with dark skies above it.

However, it's not until I leave Flagstaff for Las Vegas that I see what its legacy will be. Crossing from Arizona into Nevada at Bullhead City—90 miles from Sin City—most of the sky is inky black and star-studded, but the low northern sky is already crowned in an orange glow. At Searchlight, 60 miles out, the north is lost. An hour later from Downtown Las Vegas I could see only Jupiter, Capella and Rigel.

Light pollution in Las Vegas and countless other urban areas is growing fast, and most stargazers must now drive many hours to escape the glow.

True darkness is practically inaccessible. That's not the case in Flag, where lighting ordinance means that just a 10 minute drive finds the kind of sky few people ever get to see. In a world of rampant and unstoppable urbanization, this small town can have a huge legacy.

Brecon Beacons National Park, South Wales, UK

Location: Brecon Beacons National Park and International Dark Sky Reserve, South Wales, United Kingdom

Latitude: 51 degrees North

Altitude: 305 m

Best time to visit: May-September

Visitors to London can stand on the world-famous Greenwich Meridian Line at zero degrees longitude, but the growth of light pollution has made astronomy at Greenwich Observatory all but a memory. However, the UK has some of the largest areas of dark sky in Europe just a few hours drive away from the capital. The most beautiful is the Brecon Beacons National Park in South Wales, whose 520 square miles of forest and upland were recognized in 2013 as an International Dark Sky Reserve.

Spreading the Word

The Brecon Beacons gets its name from the ancient tribal practice of lighting 'beacon' fires on the tops of the area's prominent peaks to communicate, though it's the national park's new status that's helping to spread the word among stargazers. "A lot of people have heard of the International Dark Sky Reserve and they come here specially," says Richard Cooke, who runs *Stargazers Retreat* (Fig. 15.13), a converted stables with unfettered access to a superb custom-built private observatory.

The visual limiting magnitude of two nearby reservoirs, Crai and Usk, has been measured at +6.4 and +6.37, respectively. That's about 10,000 stars visible to the naked eye, which is just about as many as any stargazer can

Fig. 15.13 The Brecon Beacons International Dark Sky Reserve is primed for astro-tourism. © Jamie Carter

ever hope to see. Crai and Usk are both are Dark Sky Discovery Sites, but *Stargazers Retreat* is between the two, and on higher ground with clear views to the horizon in the east and south. "A lot of stargazers come here and can't believe how much more they can see in a dark sky environment just with the naked eye—you can see magnitudes more," says Richard. "When you have stars 360 degrees around you, it really brings the sky to life. It's like exploring a new world."

Ten Thousand Stars

The Brecon Beacons has much more than 10,000 stars; this is an area adored by hikers and walkers, while the vast forests surrounding it make this as much a rural retreat as a dark sky destination. Richard tells me that he has plenty of guests that come to *Stargazers Retreat* simply to escape the city, but the eye-full of stars that greets them often kick-starts an interest in the night sky. "It's amazing how many people haven't even looked at the Moon," says Richard, bemused as to why those living in light polluted areas don't study our satellite. "Looking at the shadows coming off the Moon's mountains along the terminator line always blows me away, and you don't even need dark skies."

Cold Comforts

For those after the very darkest, clearest skies, winter is the best time to visit the Brecon Beacons, which does mean freezing temperatures. "I always tell guests to bring extra warm clothes because they're going to want to be outside for at least a couple of hours," says Richard. Even during my visit in May the nights were very cold, and occasionally cloudy, but the observatory is well prepared. As well as soft red down-lighting below waist height, it's got built-in heaters. They're useful for the initial set-up, though they've got to be switched-off when using the telescope because the heat interferes with the optics. "Heat causes very small fluctuations around the telescope that you can't see until you look through the eyepiece—even planets are wobbly," he says, adding that the heaters are of most use during the winter when clouds sweep over and everyone has to wait. "You can stargaze a lot longer without freezing, though flasks of hot drink also work well."

The Fight Against Light

Its status as an International Dark Sky Reserve isn't just a recognition of the dark skies above the Brecon Beacons, but a commitment to both protect and restore them with lighting regulations. "We've got a five year plan to reduce light pollution," says Ruth Coulthard at the Brecon Beacons National Park Authority, who was involved in the bid for International Dark Sky Reserve status. "The International Dark-Skies Association has asked us to make all of the lighting in the park dark sky-friendly, and we're on about 67 %. We have to keep on making progress." Unlike in Flagstaff, where the fashion for LED lights is a major cause for concern given their need for precise astronomical observations, the authorities in the Brecon Beacons have only practical guidance for its residents. "We recommend people angle their lightning downwards and don't use them when they don't need to," says Ruth, who says the tactic has been surprisingly effective. "Light pollution isn't light itself, it's unnecessary light that spills out away from where it needs to be." Though there are 33,000 people living inside the boundaries of the national park, the biggest light-polluter is the market town of Brecon, but even here the community is increasingly interested in helping keep skies dark. "Lots of local people ask us how they can make their buildings dark sky-friendly," says Ruth, who's confident that the skies above this newest International Dark Sky Reserve will only get darker. Despite that, the advice for stargazers is to avoid Brecon altogether and head for the darker western side of the national park.

A Stargazing Schedule

Back at *Stargazers Retreat* firmly in the western zone, Richard offers a few tips on savvy stargazing. As well as giving your eyes enough time to get dark-adapted, he advises knowing how to operate a planisphere and, if you want to make the most of your time, knowing exactly what you want to see. "Have a list before you go out, then you've got goals to work towards. Otherwise you're just looking at dots in the sky and getting cold," he says. "If you know what you want to find and tick them off as you go, your enthusiasm for doing it again will be so much higher."

For my own visit I had an observing list, prepared back at home in the city, for my visit, but the skies were so dark that it quickly went out of the window. That was partly down to the appearance of Saturn, rising above Antares. The latter in binoculars was the brightest orange I had ever seen it. Its accomplices in the head of Scorpius were especially bright too, though at these mid-northern latitudes the stinger below never rises.

Point and Shoot

The observatory at *Stargazers Retreat* isn't just warm and red, it's also motorized. Hooked-up to free planetarium software Stellarium, the Meade ETX-125EC telescope is a point and shoot affair. While it's slewing to Saturn, I notice that two constellations that often get rubbed-out by urban skies, Corona Borealis (Chap. 6) and Coma Berenices (Chap. 5), are obvious above. The seven stars of Corona Borealis are unmistakable, particularly the jewel in the so-called Northern Crown, Alphecca.

More of a treat was Coma Berenices, the scant three-pronged constellation strung between Bootes and Leo that tends to disappear with even a whiff of light pollution. Inside it the Coma Cluster was an easy naked eye target, as were the two brightest stars of the tiny Baby Giraffe asterism (Chap. 6) near Cor Caroli. Above me the Big Dipper, wrapped in an obvious Ursa Major, dominated as a vast anchor.

Telescope Tutorials

I used the telescope to hunt-down a few globular clusters, though many visitors to *Stargazers Retreat* bring their own telescopes. "A lot of people who bring their own telescopes don't know how to use them," says Richard, who offers to show them how to set them up and align them in the dark. That's not a skill to underestimate, and certainly not one that comes naturally to most casual stargazers. With a box full of accessories, spares, various camera adaptors and webcams in the observatory, we're soon taking pictures of Saturn, and even filming a short video of the planet in motion. Tracking objects in the night sky is a fabulous skill of motorized telescopes, but sometimes it's more dramatic to watch a planet speeding across the field of view.

All-Weather Stargazing

The Brecon Beacons demands a much slower look. It's best to hang around for at least three nights because while most places get clear skies or bad weather, Wales often gets both at once. It's one of the few places where it's possible to stargaze while getting wet, and one of the reasons why *Stargazers Retreat* has plans for all-weather sky-watching. Construction of a small planetarium is taking place in the woodland during my visit; the aim is to eventually have both a live projection of the sky and completely remote viewing via the telescope. That will be great on a wet day, but when the clouds part above this International Dark Sky Reserve you'll want to be outside to witness what the Brecon Beacons has to offer; an awesome view of the Universe from one of its most beautiful corners.

Inca Trail and Machu Picchu, Peru

Location: Urubamba Valley near Cuzco, Southern Peru

Latitude: 13 degrees South

Altitude: 13,776 ft/4,200 m

Best time to visit: April through November

Peru isn't much known for its night skies. Perhaps it's because of the proximity of the Atacama Desert in Chile, which houses some of the world's largest, most important and highest telescopes in the world. How can the forested Peruvian Andes compete with that?

It's all about altitude. The famed Inca Trail hike that leads into one of the world's most well known tourist attractions, the lost Inca city of Machu Picchu, also offers some of the darkest, most dramatic night skies on the planet thanks to its position on the high Altiplano.

At its highest point, the Inca Trail hits an astonishing 4,200 m (13,776 ft), and while the campsites along the way aren't quite that high, they're about as close to the stars as it's possible to get. If the weather holds (and that's no guarantee in the High Andes) the skies aren't dark, they're transparent, and ablaze with stars.

Southern Sky

Most tourists tread the Inca Trail's 27 miles of arduous steps for both a sense of achievement and for the prize of seeing Machu Picchu in the light of dawn. Treks are organized out of the city of Cusco, already 11,150 ft above sea level. It's best journeyed to slowly to lessen the chance of altitude sickness.

The trails itself is all about mountain vistas and the Inca culture along the way, but there's plenty of the latter to see after dark, too. In these equatorial skies there are plenty of stars both familiar and strange to northern hemisphere stargazers; it's the perfect latitude to add to your knowledge of the southern hemisphere's quixotic night sky (Chap. 13) without getting too confused.

Fig. 15.14 The Phuyupatamarca campsite offers the dramatic Vilcambama mountains and a panoramic view of the night sky. © Gill Carter

Dark Constellations

As well as learning about new stars, and seeing old stars from a new perspective, Peru is a great place to see the Milky Way in all of its glory. Down here the extra half-a-sky of Milky Way is more brilliant, brighter and bigger than the sections visible from the northern hemisphere. However, the distinction between studying the stars and admiring the Milky Way was one I brought with me; Western stargazers tend to treat the Milky Way and constellations as two different sights. Not so in Peru, where the shapes within the Milky Way are actually the night sky's key constellations, as I learned at Planetarium Cusco, a small observatory on a hillside above the former Inca city.

The Black Llama, the Baby Lama, the Snake, the Fox, and the Frog. These are the dark constellations made not from joining-up stars, but from describing the shape of darkness between the stars within the Milky Way, which the Inca called *mayu*, or river. Used by the Inca and still familiar to the local Quechua people of Peru today, it's perhaps the Black Llama that's the most impressive Inca constellation; not only is this dark shape easy to see on a clear night, but its eyes consist of Alpha and Beta Centauri, the nearest two stars to our own solar system. Look into the eyes of the llama and you're looking at our neighbors. Planetarium Cusco is a great place to get acquainted with the Inca constellations ahead of an attempt at the Inca Trail (or any other multi-day hike in the vast Sacred Valley area), but it also lets you gets eyes-on through a telescope with some special southern hemisphere sights such as the Jewel Box Cluster and the endless clusters and nebula around the Southern Cross. Waterproof binoculars in a backpack are a must.

Moonless Mayu

The Milky Way is usually something that can only be glimpsed. Beautiful astro-photography is now familiar to everyone thanks to the internet and social media, with the Milky Way so often depicted as arching from one horizon to another in purples, oranges, greens and reds. Consequently, when most people finally see it they're disappointed. It's neither as bright nor as colorful as they had expected. Most people don't notice it even when they're in a dark sky zone.

From the Inca Trail, *mayu* is impossible to ignore. If walking during a New Moon (the golden rule of any pre-planned high altitude hike) and under clear skies, it's right there, hanging over your campsite and stretching down behind the mountain peaks. If you're camping, it's one of the few times that your eyes adapt to the dark as it gathers; stargazing can commence during twilight and, this near the equator, that means about 6 pm.

Choose Your Campsite Carefully

Although the hike itself can often mean entire days in wet cloud forests, in May the night skies are often clear. It's all about where you pitch your tent; the dramatic campsite at Phuyupatamarca that overlooks the Vilcambama mountain range has an entrancing, wide-open sky. Here, you're above the clouds and in prime position for a chilly, but beautiful evening's stargazing. However, few guided hikes pitch their tents at Phuyupatamarca; most push on to the Winay Wayna campsite deep in the forested valley (and a poor place for stargazing) to get their guests (much) closer to Machu Picchu. Almost everyone wants to be at Machu Picchu's Sun Gate for dawn, but if you opt to camp at Phuyupatamarca, you'll never make it before about 8 am. The consolation prize is anything but; probably the finest view of the night sky—and certainly of the Milky Way—it is possible to witness.

Machu Picchu's Celestial Maps

After three days of trekking, arriving at Machu Picchu is a relief, but the star lore is only just beginning; in the central courtyard you can see the Southern Cross in daylight. The distinctive four-pointed shape, such a fixture of the southern night sky, is depicted by a carved rock outside the Sun Temple (Fig. 15.15). A couple of pebbles just a few feet away could represent the pointer stars, Alpha and Beta Centauri.

In the Temple of the Sun there's also a window that frames both the beautiful Corona Borealis constellation (Chap. 6) and the rising Sun at the June solstice.

Fig. 15.15 The Southern Cross carving at Machu Picchu, Peru. © Jamie Carter

No one knows for sure what the unique celestial design of Machu Picchu means, only that it has one. Look at the clarity of the stars from the Urubamba Valley, it's perhaps not surprising, but this is a night sky you have to work for. While the day-trippers to Machu Picchu must stay in Aguas Calientes in a valley far below the lost city, only hikers enduring the Inca Trail's seemingly endless high-altitude path get the full, breathtaking experience of a staircase to the stars.

Dark Skies Bucket List

Stargazing is the perfect excuse to travel. Now you have a trained eye in what to look for, it's time to get out into the Universe and see it in the world's darkest places.

Fig. 15.16 Hawaii has 325 clear nights a year, and the northern hemisphere's biggest telescopes including Keck, Subaru and Gemini. Credit: Hawaii Tourism Authority (HTA)/Dana Edmunds & www.gohawaii.com

Mauna Kea, Hawaii

Location: Hawaii

Latitude: 20 degrees North

Altitude: 9,200 ft/2,804 m

Best time to visit: Anytime

With around 325 clear nights every year, the 13,796 ft summit of Mauna Kea in Hawaii (Fig. 15.14) is stargazing royalty (Fig. 15.16). Home to some of the world's largest telescopes, the Visitor Information Station at 9,200 ft has a nightly stargazing program while plenty of operators run stargazing trips that include looking through large portable telescopes. On the adjacent island of Maui a visitor center at 10,000 ft in Haleakala National Park also hosts an observatory, with several solar telescopes.

Sahara Sky Observatory, Morocco

Location: Kasbah Hotel, Draâ Valley, Morocco

Latitude: 30 degrees North

Altitude: 680 m

Best time to visit: November through March

Look at a map of the world and it's Africa that has the least light pollution. It's the vast Sahara desert in North Africa that keeps this hotel observatory in the dark, with a huge range of telescopes and an astronomer on hand, too. With a complete 360 degree panoramic view of the magical desert landscape and low horizons in every direction, the Sahara Sky Observatory promises full immersion.

Alpine Astrovillage Lü-Stailas Observatory and Center for Astrophotography, Switzerland

Location: Val Müstair-Schweizer National Park, Switzerland

Latitude: 47 degrees North

Altitude: 6,300 ft/1,935 m

Best time to visit: April through October

Ever fancied yourself as an astro-photographer? The Swiss Alps may not be the most obvious place for an amateur astro-photography center, but this observatory within the UNESCO Biosphere region of Val Müstair-Schweizer National Park is 6,348 ft above sea level, devoid of light pollution and hosts 250 clear nights each year. Its multi-day residential courses include Observation for Beginners, Deep Sky Photography with a DSLR, and separate courses for Observation and Photography of both the Moon and Sun. Domes can also be rented for long-term projects. During the day, cross-country skiing tracks are nearby, while downhill skiing at St. Moritz is only an hour by car.

Galloway Forest International Dark Sky Park, Scotland

Location: Dumfries and Galloway, Scotland, UK

Latitude: 55 degrees North

Altitude: Sea-level

Best time to visit: October through March

Oceans, deserts and mountains are often thought of as the pillars of a dark sky wilderness, but the vast Galloway Forest Park in south-east Scotland has other ideas. Although stargazing through the canopy of 300 square miles of birch, beech and larch trees might not sound particularly easy, various gold-tier Dark Sky Discovery Sites are dotted throughout complete with car parks and star-charts. The finest is Clatteringshaws Visitor Centre, which has an open view over a loch and the very darkest area of the park. Galloway Forest's latitude means you might just get a glimpse of the Northern Lights. A short drive to the south-east gets you to Northumberland National Park and Kielder Water and Forest Park, the latter another International Dark Sky Park.

Fig. 15.17 Chile's Atacama Desert is home to the European Southern Observatory. Credit: ESO

Elqui Valley, Chile

Location: Atacama Desert, Chile

Latitude: 24 degrees South

Altitude: 13,000 ft/4,000 m

Best time to visit: October/November or March/April

Northern Chile and the Atacama Desert area of Chile is home to one third of the planet's telescopes. This astronomy HQ's boasts the clearest view of the night sky anywhere in the southern hemisphere as well as 300 cloudless nights a year, though October/November or March/April are the best times to visit if you want to avoid mass-tourism. Paranal's European Southern Observatory can be visited (Fig. 15.17), though of as much interest to stargazers is the Mamalluca Tourist Observatory in the Elqui Valley, which has guided visits every night.

Southwest USA

Location: Arizona, California, Nevada, New Mexico and Utah

Latitude: 36–31 degrees North

Altitude: Various

Best time to visit: Year-round

The eastern half of the USA is awash with light pollution. There are some dark spots (such as Cherry Springs State Park in Pennsylvania), but most are in the southwest. In fact, there are more than ten International Dark Sky Parks in Arizona, California, Nevada, New Mexico and Utah, where clear skies and low humidity give year-round stargazing potential.

The darkest is reckoned to be Natural Bridges National Monument in southeast Utah, the first (and some say best) International Dark Sky Park, Park, though Arches National Park nearby is just as dark. In the south-west of the state is the ever-popular Bryce Canyon National Park (which holds stargazing lectures and guided observing every week in summer), and the lesser-known but super-dark Cedar Breaks National Monument near Brian Head and Cedar City. That the National Park Service in the USA is now fighting to protect, preserve and improve the darkness of its skies is a huge help for stargazers in North America. There are also several observatories to choose from that host public observing sessions, including Lowell Observatory in Flagstaff, Arizona, Kitt Peak National Observatory southwest of Tucson, Arizona, and McDonald Observatory near Fort Davis, Texas.

Aoraki Mackenzie International Dark Sky Reserve, New Zealand

Location: South Island, New Zealand

Latitude: 44 degrees south

Altitude: 3,379 ft/1,030 m

Best time to visit: Year-round

A gold-rated International Dark Sky Reserve and the largest in the southern hemisphere, the 2670 square miles of Aoraki Mackenzie in the South Island of New Zealand includes Mt John Observatory at Lake Tekapo, New Zealand's foremost observatory. Several day and night tours of the observatory are available as well as guided stargazing tours. Like Flagstaff, the Aoraki Mackenzie's transparent skies are down to lighting ordinance, which has been in place since 1981.

NamibRand International Dark Sky Reserve, Namibia

Location: Northern Namibia, southern Africa

Latitude: 25 degrees South

Altitude: 2,700 ft/823 m

Best time to visit: May through July

A safari is an ideal way of spending time under very dark skies without having to convince spouses and/or family to join in with your hobby. But what if you get to a safari lodge and it's lit-up like a Christmas tree? That won't happen in NamibRand, southern Africa's largest private nature reserve and now an International Dark Sky Reserve, which means subtle lighting at safari lodges and protected dark skies.

The nearest neighboring communities are 60 miles distant, though the desert elephants, reptiles, springbok, ostriches and baboons in the NamibRand Nature Reserve mean you won't want to wander off into the wilds at night to stargaze.

Zselic National Landscape Protection Area, Hungary

Location: South-west Hungary

Latitude: 46 degrees North

Altitude: 928 ft/283 m

Best time to visit: March through October

An International Dark Sky Park since 2009, Zselic Landscape Protection Area is Eastern Europe's darkest place. South of Lake Balaton in south-west Hungary, Zselic has attracted astronomers for decades and has only fully shielded lights within its borders.

The Far Side of the Moon

Location: the Sea of Moscow, the Moon

Latitude: N/A

Altitude: N/A

Best time to visit: during Full Moon

OK, so this one isn't on the tourist trail yet, but we can hope. Devoid of any of the distorting atmosphere that can affect the brightness and stability of stars from here on Earth, the very finest place to stargaze from would be the side of the Moon that always faces away from us (Fig. 15.18). It was mapped by the Soviet Union in 1959, so the features all have Russian names.

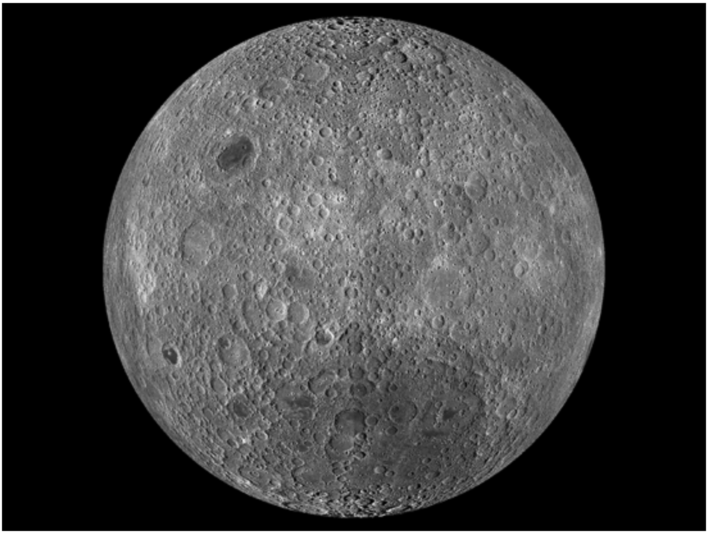

Fig. 15.18 The far side of the Moon would be the ultimate dark sky destination. Credit: NASA/Goddard/Arizona State University

As viewed from the Moon, the stars would be about a third brighter than they appear to be when observed from Earth.

For stargazers and astronomers, the other side of the Moon (which no human has yet set foot on) could become a favorite vacation spot of the future, with 24-hour stargazing possible during the Full Moon. Why not?

Dark Sky Destinations: Contacts and Resources

International Dark-Sky Association

www.darksky.org

Australia

Cosmos Centre and Observatory, Charleville, Queensland

enquiries@cosmoscentre.com

www.cosmoscentre.com

Chile

Chile Tourism

chile.travel/en

European Southern Observatory

Weekend tours to Paranal, La Silla and ALMA observatories

www.eso.org

Turismo Astronomie (observatory tours)

www.astronomictourism.com

Finnish Lapland

Adventure By Design (aurora photography expeditions)

adventurebydesign.fi

Aurora Zone

www.theaurorazone.com

France

Observatoire du Pic du Midi and Pic du Midi International Dark Sky Reserve, Hautes-Pyrénées

www.picdumidi.com

Hungary

Zselic National Landscape Protection Area and International Dark Sky Park

zselic.csillagpark.hu

Hawaii

Hawaii Tourism Authority

www.gohawaii.com

Mauna Kea Observatories

www.ifa.hawaii.edu/mko

Haleakala National Park

www.nps.gov/hale

Mauna Kea Summit Adventures

www.maunakea.com

Morocco

SaharaSky Observatory and Kasbah Hotel

www.saharasky.com

www.hotel-sahara.com/hotel

New Zealand

Aoraki Mackenzie International Dark Sky Reserve

www.mtcooknz.com/mackenzie/stargazing

Namibia

NamibRand International Dark Sky Reserve

www.namibrand.com

Peru

Planetarium Cusco

www.planetariumcusco.com

Machu Picchu World Heritage site

www.machupicchu.gob.pe

Scotland, UK

Galloway Forest International Dark Sky Park

scotland.forestry.gov.uk/forest-parks/galloway-forest-park

Scottish Dark Sky Observatory

www.scottishdarkskyobservatory.co.uk

Switzerland

Alpine Astrovillage Lü-Stailas Observatory and Center for Astrophotography

www.alpineastrovillage.net

Tenerife, Spain

Parque Nacional del Teide

www.telefericoteide.com

Parador de Canadas del Teide Hotel

www.parador.es

USA

Big Bend National Park and International Dark Sky Park, Texas

www.nps.gov/bibe

Bryce Canyon National Park Astronomy & Night Sky Programs

www.nps.gov/brca/planyourvisit/astronomyprograms.htm

Capitol Reef National Park and International Dark Sky Park, Utah

www.nps.gov/care

Chaco Culture National Historical Park International Dark Sky Park, New Mexico

www.nps.gov/chcu

Cherry Springs State Park International Dark Sky Park

www.dcnr.state.pa.us/stateparks/findapark/cherrysprings

Cedar Breaks National Monument

www.nps.gov/cebr

Copper Breaks State Park and International Dark Sky Park, Texas

tpwd.texas.gov/state-parks/copper-breaks

Death Valley National Park International Dark Sky Park, California

www.nps.gov/deva

Enchanted Rock State Natural Area and International Dark Sky Park, Texas

tpwd.texas.gov/state-parks/enchanted-rock

Flagstaff Dark Skies Coalition

www.flagstaffdarkskies.org

Grand Canyon National Park

www.nps.gov/grca

Hovenweep National Monument and International Dark Sky Park, Utah/ Colorado

www.nps.gov/hove

Inn at 410 B&B, Flagstaff

www.inn410.com

Kitt Peak National Observatory, Tucson, Arizona

www.noao.edu/kpno

Lowell Observatory, Flagstaff

www.lowell.edu

McDonald Observatory, Fort Davis, Texas.

mcdonaldobservatory.org

Natural Bridges National Monument and International Dark Sky Park, Utah

www.nps.gov/nabr

Oracle State Park and International Dark Sky Park, Arizona

azstateparks.com/parks/orac

Parashant International Night Sky Province

www.nps.gov/para

Weber County North Fork Park and International Dark Sky Park, Utah

www.co.weber.ut.us

Wales, UK

Brecon Beacons National Park and International Dark Sky Reserve

www.breconbeacons.org/stargazing

Llangoed Hall

www.llangoedhall.co.uk

Stargazers Retreat

www.breconcottages.com/cottages/brecon/stargazers-retreat

Reference

Childrey, Don. Star Trails Navajo: A Different Way to Look at the Night Sky. Trafford Publishing, Canada, 2004.

APPENDIX

Stargazing Resources

Stargazing Websites

BBC Sky At Night magazine: www.skyatnightmagazine.com

Cosmic Pursuits: http://cosmicpursuits.com

EarthSky: www.earthsky.com

Heavens Above: www.heavens-above.com

Jodrell Bank Centre for Astrophysics, The Night Sky: www.jb.man.ac.uk/astronomy/nightsky

Moon Connection: www.moonconnection.com

Sky & Telescope magazine: www.skyandtelescope.com

Solarham: www.solarham.net

Space Weather: www.spaceweather.com

Stargazers Lounge: www.stargazerslounge.com

Universe Today: www.universetoday.com

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7

Eclipse Websites

Eclipser (climatology and maps for eclipse chasers): eclipser.ca/

NASA Eclipses (dates and durations): eclipse.gsfc.nasa.gov/eclipse.html

Mr Eclipse (eclipse photography): www.mreclipse.com/

Stargazing Podcasts

Astronomy Cast with Fraser Cain & Dr Pamela Gay

www.astronomycast.com

Jodcast: The Night Sky This Month with Ian Morison

http://www.jb.man.ac.uk/jodcast

Sky & Telescope: Sky Tour Podcasts—Discover the Night Sky

www.skyandtelescope.com/observing/astronomy-podcasts

Planetarium Software and Desktop Apps

Cartes du Ciel/Skychart (freeware): www.ap-i.net/skychart/start

SkySafari: www.southernstars.com

Stellarium (freeware): www.stellarium.org

Smartphone and Tablet Apps

Aurora Fcst: www.tinacinc.com/AuroraForecast/

AuroraWatch UK: aurorawatch.lancs.ac.uk/alerts

Luna Solaria (Moon phases): www.lunasolaria.com

Moon Globe HD: midnightmartian.com/MoonGlobe

SkySafari: www.southernstars.com

Star Walk: vitotechnology.com/star-walk

Stellarium Mobile Sky Map: www.stellarium.org

Further Reading

Beston, Henry. The Outermost House: A Year of Life on the Great Beach of Cape Cod. St. Martin's Griffin, New York. 1988.

Bogard, Paul. The End Of Night: Searching for Natural Darkness in an Age of Artificial Light. Fourth Estate, London. 2013.

Chiravalle, John A. Pattern Asterisms: A New Way to Chart the Stars. Springer-Verlag London (2006)

Consolmagno, Guy & Davis, Dan M. Turn Left at Orion: 4th Edition. Cambridge University Press, Cambridge. 2012.

Morrison, Ian. Introduction to Astronomy & Cosmology. Wiley-Blackwell, London. 2008.

North, Chris & Abel, Paul. The Sky At Night: How To Read The Solar System. BBC Books, Random House, London. (2013)

Sagan, Carl. Cosmos: unabridged edition. Random House Publishing Group, USA. 2011.

Scale, Robin. The Urban Astronomy Guide: Stargazing From Towns & Suburbs. Philip's, London. (2014)

Seronik, G. Binocular Highlights: 99 Celestial Sights for Binocular Users – Sky & Telescope Stargazing. Sky Publishing, USA. 2007.

Sparrow, Giles. The Universe And How To See It: A Practical Guide To Viewing & Understanding The Night Sky. Marshall Publishing, London. (2001)

Tonkin, Stephen. Binocular Astronomy, Second Edition. Springer New York Heidelberg Dordrecht London. 2014.

Index

J. Carter, *A Stargazing Program for Beginners*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-22072-7